Strategic Environmental Research and Development Program (SERDP)

Sustainable Forward Operating Bases

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noblis

For the best of reasons

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Executive Summary

Current United States military contingency operations underscore a need for more sustainable forward operating bases (FOBs). FOBs have been vital in supporting the expeditionary and campaign capabilities of the U.S. military, but building and sustaining FOBs have incurred significant costs in terms of both dollars spent and lives lost.

This report was prepared for the Strategic Environmental Research and Development Program (SERDP) and attempts to characterize current FOB design and operations as a first step towards developing more sustainable FOBs (a summary characterization is provided in Appendix A). It is intended as an overview to guide initial discussions and assist SERDP in identifying potential research investments. The scope of this report is limited to a survey of primary FOB sustainability concerns and includes discussion of FOB types, elements of planning and sustainment, force protection, food, water, wastewater, fuel and power, and solid waste. Detailed analyses and research recommendations are reserved for future study.

FOBs can vary depending on size, mission, duration, type of unit supported, area of operations, and the availability / sophistication of host-nation infrastructure. FOBs can range from austere, platoon-sized bases on the tactical edge to division-sized enduring bases. The amount of materiel required and rate of waste generated will differ between different FOB types, but the fundamental problems remain the same. By reducing the amount of support materiel needed, designing more sustainable FOBs will have a direct impact on logistics costs, potential casualties, and U.S. combat force effectiveness.

Improving the sustainability of FOBs will require extensive coordination among multiple parties and careful navigation of complex tradeoffs. Given the relevance of the subject, teams across the federal government, the Department of Defense, and the military Services have started initiatives to design more sustainable FOBs. While some initiatives focus on current commercial solutions and others emphasize long-term research, collaboration and knowledge-sharing across all parties will be critical to developing solutions in a timely manner.

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1 Introduction

1.1 Overview

Noblis was tasked by the Strategic Environmental Research and Development Program (SERDP) to identify and characterize the logistical components and practices required to develop, build, and sustain Forward Operating Bases (FOBs). This snapshot of current operational requirements can then be used by SERDP to identify and explore additional research opportunities in sustainable FOB design.

This paper will provide a brief review of:

1. FOB types (role, differences based on size, mission, Service, area of operation, and duration)
2. FOB construction planning process
3. Supply considerations
4. Structures and facilities at FOBs
5. Quantity, composition, and current operational practices associated with food, water and wastewater, energy/power/fuel, and solid waste streams
6. Next steps and parallel research efforts

1.2 Relevance

The sustainability of our FOBs in Iraq, Afghanistan, and around the world has never been a more relevant issue. Recent troop surges and extended operations in multiple theaters underscore the urgency for improved FOB sustainability to reduce costs, logistic support, force exposure, and casualties. Without renewable power, as Major General Richard Zilmer said in an oft-quoted remark, U.S. forces "will remain unnecessarily exposed" and will "continue to accrue preventable… serious and grave casualties."[1]

Dr. Ash Carter, the Under Secretary of Defense for Acquisition, Technology, and Logistics, has commented that "protecting large fuel convoys imposes a huge burden on combat forces" and "reducing the fuel demand would move the department more towards an efficient force structure by enabling more combat forces supported by fewer logistics assets, reducing operating costs, and mitigating budget effects caused by fuel price volatility."[2]

FOB sustainability issues extend far beyond efforts to consolidate forces and bases in Iraq and shift the focus to Afghanistan. Both the challenges we face today and the benefits from bridging the gap to more sustainable FOBs will extend to future conflicts and locations.

1.3 Definitions

We use the term *Forward Operating Base* (FOB) to include all relevant Service-unique and U.S. Central Command (CENTCOM) designations for facilities in support of expeditionary or contingency operations, including: forward operating base, contingency operation base, main operations base, camp, combat outpost, patrol base, base complex, tactical base, logistics base, logistics support area, intermediate staging base, fire base, and enduring base.

Differences in process and characterization of input/output streams that are dependent on the size/type of FOB will be identified and addressed in the following sections.

1.4 Approach

As part of the research process to develop this paper, Noblis conducted interviews with representatives throughout the federal government and U.S. military, performed an extensive literature review on doctrine, guidance, private and public sector research, anecdotal first person accounts, and public articles, and attended conferences, symposiums, and workshops on energy, sustainability, and the corresponding impact on the military. Although not within the scope of this particular effort, Noblis also briefly assessed areas of potential research that warrant additional consideration.

Though the purpose of this paper is to provide an overview of FOBs, key points are highlighted throughout and may provide a basis for continued research. Identification of best practices, recommended approaches, sustainability principles, and specific research to address FOB design and operations will require more detailed analyses and future study.

2 Forward Operating Bases

Highlights

- FOBs are critical to the U.S. expeditionary warfighting strategy
- Establishing and sustaining FOBs require significant logistical support
- FOBs can vary widely in sophistication, depending on size, support requirement, host-nation infrastructure, the nature of the operation (contingency, enduring), and anticipated duration (temporary, semi-permanent, permanent)

Implications for Future Research

- Solutions must be geography-neutral. Solutions can be inspired by need in one region, such as spray-foaming tents for insulation in Iraq or Afghanistan, but the ebb and flow of soldiers in Iraq and Afghanistan suggest that solutions should not be relevant for only one geography type. Planners must anticipate the next contingency operation.
- Solutions must be modular, flexible, scaleable, and adaptable for the spectrum of FOB types, from austere, platoon-sized bases to full, division-sized main bases.

2.1 Role of FOBs

Although the total tally and specific location of FOBs are unavailable to the public, reports currently place the total number of U.S. and coalition FOBs (as we have defined the term above) at approximately 400 in Afghanistan and 300 in Iraq.[3] Although the current plan is to consolidate the FOBs in Iraq into anywhere from 14-50 'enduring bases' following the August 31, 2010 deadline to remove U.S. combat forces from Iraq, the 400 bases in Afghanistan represents a significant increase since CENTCOM announced that there were 100 bases in Afghanistan in November 2008.[4] This building boom is directly correlated with the amount of money spent on base construction, with reports indicating $3b worth of work currently in Afghanistan and $3.2b in Iraq, a significant increase over the $4.5b spent by the U.S. Army Corps of Engineers (USACE) between 2002 and 2008.[5]

These numbers represent how integral FOBs have become to the U.S. expeditionary warfighting strategy. Simply defined, the FOB is an "evolving military facility that supports the military operations of a deployed unit and provides necessary support and services for sustained operations", with a particular focus on supporting *expeditionary capabilities* (the ability to deploy combined arms forces into any operational environment and operate effectively upon arrival) and *campaign capabilities* (the ability to sustain operations as long as necessary to conclude operations successfully).[6] FOBs have become the hallmark of U.S. contingency operations and pose both distinct advantages and challenges to the participants in U.S. contingency operations:

- To the operators, FOBs are critical in waging asymmetric warfare. As one Army captain described, "co-locating in population centers enabled us to deny the enemy access to the local population, influence and assist the local government, provide security, and to train the local police and army units to provide their own unaided security. Over the course of nearly a year, the platoon leadership developed strong relationships with locals that allowed the leadership to maintain a constant 'read' on the population and insurgents, providing the chain of command with bottom-up intelligence for the planning of missions."[7]
- To the soldier, FOBs help reduce "the psychological toll of warfare" as they "give soldiers an unprecedented advantage of gaining a respite from constant danger, minimize the wearing effects of hunger and fatigue, and reduce the isolation of combat."[8]

- To the logistician, FOBs quickly "become the focus of a massive logistical effort" as building and sustaining FOBs in remote areas necessitate huge expenditures of resources.[9] While offering benefits, co-locating U.S. forces with the indigenous population also creates easier targets for enemy fire and adds to the cost of protecting supply lines and convoys.

2.2 Types of FOBs

Although we have defined FOBs broadly to encompass all contingency bases, FOBs can differ greatly based on mission type, duration, size, role, Area of Operation (AOR), host-nation infrastructure, Service, and units supported – from an austere, platoon-sized base on the tactical edge to division-sized enduring bases that sell flat screen televisions from their Post Exchange (PX). Table 1, FOB Types, illustrates how U.S. military doctrine uses different duration, size, and base type distinctions in classifying types of FOBs and base camps. Authorized buildings, type of amenities, and – of particular relevance for this paper – the energy, fuel, water, and waste treatment standards for a FOB will depend on these classifications. Additional information on how facility standards can differ is provided in Appendices A through D. Appendix A provides the summary characterization of current FOBs. Appendix B provides a snapshot of facility standards based on U.S. Army Field Manual (FM) 3-34. Appendix C provides an overview of USACE contingency construction standards. Appendix D provides a comparison of authorized facilities at FOBs, Main Base Camps, and Outposts according to the United States Army, Europe (USAREUR) Base Camp Facilities Standards (commonly referred to as the "Red Book")..[10]

Table 1. FOB Types

By Duration					
US Army Corps of Engineers			**Contingency**		**Enduring**
	Organic < 90 days	Initial < 6 months	Temporary < 24 months	Semi-permanent	Permanent
Army FM 3-34		Initial < 6 months	Temporary 6 - 24 months	Semi-permanent 2 - 10 years	
USAREUR "Red Book"		Initial < 6 months	Temporary 6 - 24 months	Semi-permanent 2 - 25 years	
USCENTCOM			**Contingency**		**Permanent**
"Sand Book"	Expeditionary	Initial	Temporary		
By Base Type	**Forward Operating Base**		**Main Operations Base**		**Enduring Base**
By Size	**Platoon - Company**		**Battalion - Brigade**		**Division**

Generally, a division has 10,000 to 20,000 soldiers, a brigade 2,000 to 5,000 soldiers, a regiment 2,000 to 3,000 soldiers, a battalion 300 to 1,000 soldiers, a company 70 to 250 soldiers, and a platoon 25 to 60 soldiers.

A brief snapshot of the differences between FOBs:

- 10,000 soldiers stationed at 12 base camps in the Balkans as part of Operation Joint Endeavor (starting in 1995); most stationed at **Eagle Base** (1,260) in Bosnia and **Camp Bondsteel** (3,950) in Kosovo.
- FOBs "often austere, with no living quarters, latrines, or dining halls"[11]
- **Camp Leatherneck** (Afghanistan) (U.S. Marine Corps, or "USMC) was a 460 acre site of "dunes and moondust", now a 6,000 member camp, with 4,000 Marines and 2,000 contractors[12]
- **FOB Salerno** (Afghanistan): 300 acres
- **FOB Pacesetter** (Iraq): austere base with no facilities
- **FOB Altimur** (Afghanistan) looks like "fortified gravel pit on a barren slope, surrounded by two-tiered sacks of dirt and razor wire"[13]
- **Al-Asad** (Iraq) includes 20,000 people living on 18 square miles, with an internal bus system, 48 1 megawatt (MW) generators, 32 MW of continuous power demand, 1.1m gallons of water/day demand, 1.2m gallons of water/day supply, 9 water wells, Reverse Osmosis Water Purification Unit (ROWPU), water treatment facilities treating 60 gallons/person/day, 6,771 facilities, and 193 spot generators [14]
- **Camp Balad** (Iraq) has 2 power plants, 2 water treatment plants (producing 1.9m gallons of water/day), a plant that provides 7m bottles/mo of drinking water, 2 fire stations, a gym, health clinic, restaurants
- **FOB Hit** (Iraq): no running water, just tents. Only Meals Ready-to-Eat (MREs) and burning human waste
- **FOB Danger** (Iraq) has air-conditioned palaces, **FOB Speicher** (Iraq) has a Burger King and a day spa, **FOB Anaconda** (Iraq) has a swimming pool, but **FOB Brassfield-Mora** (Iraq) "isn't anywhere as nice as the other FOBs. Its PX sells mostly soda and shaving cream. Its mess hall serves MREs for lunch."[15]
- "All in all, **FOB Naray** (Afghanistan) is now home to about 500 American and Afghan soldiers, about one-third of whom are out at any one time manning the OPs and outposts for weeks-long spells. And there are no hot A's at those sites; none. I've spent some time at one. Just MREs, three times a day. And no flush toilets, no hot showers, or bathing at all, unless one is near a stream or water source. And no real electricity, except a small generator, no air-conditioning, no tents, and, heaven forbid, no internet. All of which can be found at FOB Naray. Sure, the flush toilets are all the way on the other side of the camp, unless you're counting the couple of outhouse burn-shitters on the north side. And the showers too aren't next door; they are in a conex that is a long, ankle-straining river-rock walk away across camp. There is air conditioning and heat in the winter, but the long tents are packed, 30- to 40-cots or more each, with personal space less than an arm's reach. As for the internet, except for the staff working the TOC (with internet at their fingertips, that's the benefit of being staff), there are exactly three computers hooked up in a small conex, there's a 30- minute limit, and there's always a line of guys waiting. Still, it's better than the guys up in the outposts have it, with only their dreams to communicate back home to loved ones."[16]

To add to the complexity, FOBs naturally evolve over time as missions change in scope and duration. Operation Joint Endeavor in Bosnia (1995-1996), for example, was intended to be a temporary occupation (and it was presented to host nations as such), so "tent camps were set up quickly to establish a presence and keep troops sheltered and out of the mud."[17] As is typical of an expeditionary campaign, however, "it soon became obvious that peacekeeping would require a longer commitment", leading to the replacement of military issue tents with Southeast Asia huts (SEA hut), 16x32 foot wood-frame tents modified by a metal roof, extended rafters, and screened-in areas.[18] In subsequent missions, such as in Kosovo following NATO Operation Allied Force (1999), base planners directly used SEA huts.[19]

3 Planning Process

The first element of the sustainability equation is to understand the basic planning process involved in establishing FOBs

Highlights

- Planning process characterized by decentralized management of details; extensive coordination required across a disparate set of parties
- No repository of best practices or consistent doctrine, standards
- No systematic, robust process for developing and implementing sustainable solutions
- Process characterized by tradeoffs, but mission success takes top priority

Implications for Future Research

- Solutions must have commander buy-in from the beginning
- Solutions must take into account relevant concerns from all parties
- Solutions must account for operational and political reality
- Solutions must not obstruct – but enable – mission success
- Solutions must not jeopardize soldier health, safety, or morale
- Solutions must not hinder timely FOB development

Areas of Potential Future Research

- Develop strategy roadmap towards greater sustainability with the following steps: 1) fully utilize all materiel, 2) reduce demand, 3) minimize waste through reuse of materiel, and 4) reuse generated waste
- Develop decision-support tool that incorporates sustainable best practices

While the majority of this paper will focus on the tangible quantities of fuel, water, and materiel consumed and waste produced at FOBs, it is important to understand the planning process involved in locating, designing, and constructing a FOB. There are three primary reasons why the planning process is a factor in enhancing the sustainability of FOB design: 1) decisions made in planning directly impact the commodities required to build and sustain the FOB, 2) understanding the planning process introduces the participants that must be involved in designing more sustainable FOBs, and 3) the tradeoffs of current FOB design will remain relevant in improving sustainability.

3.1 Characteristics of the Process

Decentralized Authority

With FOBs, the commander's intent guides the basic parameters of the base – location, size, combat elements, intended duration of use – but the details are handled by decentralized or local command authority. Those involved use guidance from CENTCOM's Sand Book, Red Book, and individual manuals from their respective Services, but there is no central repository of best practices and no one point of authority with a holistic perspective on the process. Although the Red Book has been in existence for some time, the Sand Book was only developed recently, and even with its implementation, most soldiers in Iraq and Afghanistan for the most part continued to treat it more as a general guide than strict doctrine. With the emphasis on achieving the military mission, implementing best practices in sustainable FOB design inevitably takes lesser priority.

Extensive Coordination Required

The planning process requires extensive coordination across a disparate set of parties.[20] After theater command/headquarters identifies a need for a FOB, planners use various tools (e.g., Theater Construction Management System, the Navy's Advanced Base Functional Components Planning and Programming System) to design the facilities. The future tenants, the supported unit, will refine the plan and engineers will start construction, often relying heavily on contractor support.[21] Throughout the process, the participants must assess the terrain, evaluate supply routes for construction, and coordinate air and ground transportation contacts. Commanders and their teams must evaluate land and supply drop zones while engineers evaluate soil conditions and force protection, contingency real estate teams legally secure the land (coordinating with host nation representatives if necessary), and logistics/engineers generate the supply request for items needed immediately to begin the construction process (e.g., concertina wire, HESCOs, lumber, plywood, sandbags, tents, power generators, MREs, bottled water, fuel). Teams might include organic combat engineering units, Army construction battalions, USACE, U.S. Army Prime Power (249th Engineer Battalion), U.S. Army Force Provider (643rd Quartermaster Company), United States Navy Construction Battalions (Seabees), and United States Air Force (USAF) 809th Expeditionary Red Horse Squadron and Prime Base Engineer Emergency Force (PRIME BEEF) Squadron.[22]

3.2 Process Tradeoffs

All parties involved have distinct concerns, and all of these concerns must be taken into account when designing (or optimizing) FOBs. These concerns, often divergent, result in a planning process that is characterized by tradeoffs. These include the need to balance:

1. The extensive process of building a FOB (effectively designing a city, complete with utilities) with many stakeholders against the need to have a FOB built quickly.[23]
2. Sustainability, environmental stewardship, and host nation relations against the demands of military operations, the imperative to protect soldiers, and mission requirements
3. The optimum, sustainable solution against political necessity and operational reality (e.g., the use of local contractors, handing out bottled water to Iraqi civilians)

The result of balancing these tradeoffs is an iterative process characterized by adaptation and compromise at every step. In designing FOBs, for example, "you either build a FOB from scratch and design it how you want", a more time consuming process that mitigates future risk, or else "make do with what you have", which emphasizes speed at the expense of risk.[24] FOB construction, another soldier writes, "was driven by immediate necessity. FOB force protection became a phased operation: first we built what we thought needed to be built. Second we assessed what the reaction the enemy had to our fortifications. Third, we developed controls based on the enemy reaction."[25] An Army representative planning process involves the following steps:

- Preliminary planning
  - Some teams will utilize a base camp planning board[26]
  - Determine primary FOB mission, duration
- Location selection

- Conduct extensive reconnaissance
- Determine whether to utilize existing government buildings/huts or build FOBs from scratch; moving into existing buildings would require less resources, but could expose soldiers to questionable infrastructure and potential health problems[27]
- FOB planning often requires at least a month before construction[28]

- Land use planning
- Facility requirements development
- General site planning
- Design guide, programming, and construction
- Maintain and update plans
- Cleanup, closure, and archive

4 Supply of FOBs

The second element in the sustainability equation is to evaluate opportunities to optimize supply strategy and execution in designing sustainable FOBs

Highlights

- The majority of materiel needed to build and sustain FOBs is brought into theater
- Redesign of supply strategy can contribute to more sustainable FOBs
- Transportation challenges differ based on geography (e.g., Iraq v. Afghanistan)
- Shipping containers can be redesigned for greater use at FOBs

Implications for Future Research

- Solutions must adhere to current infrastructure and transportation requirements

Areas of Potential Future Research

- Design materiel supply chain strategy to enhance sustainability
- Design shipping containers for use as FOB structures, force protection. Develop other creative uses for packaging material / pallets.

The fundamental consideration in forward deployment is logistics. Logistics has been a primary determinant of campaign success throughout history. Today, logistics requires half of all Department of Defense (DoD) personnel and consumes a third of its budget.[29] As General James T. Conway, the USMC Commandant, explained, the U.S. supply lines in Afghanistan "represent an operational vulnerability" and, as a result, "we are getting hit; we are losing Marines."[30] This section examines: 1) what items need to be shipped to a FOB, 2) how materiel is transported, and 3) the containerization of logistics and facilities.

4.1 What Needs to be Shipped

The majority of all materiel needed to build and sustain a FOB is brought into the theater of war rather than sourced locally, even if resupply requires extensive time (up to 45 days from source to end user in Afghanistan).[31] A perspective on the volume of materiel needed follows:

1. A 30 vehicle initial convoy was required to make one FOB adequate for living and defendable in Afghanistan; subsequently needed another 20 trucks of supplies, 8 fuel trucks, and 2 trucks carrying a Bobcat and a Small Emplacement Excavator (SEE)[32]
2. "In addition to normal logistics packages, the 411th Engineer Brigade sent more than 300 containers of lumber, concertina wire, and electrical parts to FOB Hammer" (Iraq)[33]
3. A 600 soldier FOB requires a convoy of 22 trucks per day to supply the base with fuel or water and to truck away wastewater and solid waste[34]

Any reduction in the amount of materiel needed to be shipped has a direct impact on the logistics costs and potential casualties from convoy protection. Not only does this underscore a need to consider multiple purposes for each item shipped in order to maximize its relative contribution to the FOB, but a redesign or development of new strategy to minimize the logistics tail can contribute to the overall sustainability of FOBs.

The elements of global distribution "have evolved into commodity-based supply chains aligned to military classes of supply", a reflection of a "shift in DoD support philosophy away from the traditional stock-based logistic system to a leaner, just-in-time distribution-based system" that has "reduced the traditional safety net of redundant materiel stocks."[35] Table 2, Military Classes of Supply, lists the classes of supply.

Table 2. Military Classes of Supply[36]

SUPPLY COMMODITY EXECUTIVE AGENTS

CL I Subsistence Executive Agent (EA) – DLA DODD 5101.10	**EA** - Plan for, procure, manage, ensure quality, and maintain war reserve stocks to support Service and combatant command requirements for types, quantities, and delivery. **Services** - Provide forecasts and coordinate mission transfers. **Combatant Commands** - Coordinate support for military operations.
CL II Clothing / Textiles / Individual Equipment / Tools Title 10, USC Responsibility – Services	**DLA** - Plan for, procure, and manage requirements and distribution of materiel. **Services** - Determine requirements and provide supporting distribution structure at retail level. **Combatant Commands** - Coordinate support for military operations.
CL III Bulk Petroleum, Oils, and Lubricants Subclass: Bulk Petroleum EA – DLA / Defense Energy Support Center DODD 5101.8	**EA** - Acquire, store, and distribute bulk petroleum from source of supply to acceptance by customer. Establish equipment standards and interoperability requirements. Establish customer relationships with defense agencies and friendly forces where US is designated fuels role support nation. **Services** - Provide force structure to operate tactical storage and distribution systems. **Army** - Manage overland petroleum support. **Air Force** - Provide distribution of bulk petroleum products by air. **Navy** - Provide seaward and over-the-shore bulk petroleum products. **Marine Corps** - Maintain capability to provide bulk petroleum top USMC. **Combatant Commands** - Integrate EA supply chain recommendations.
CL IV Construction / Barrier Materiel EA – DLA DODD 5101.12	**EA** - Plan for, procure manage, and supply materiel required by DOD components. **Services** - Provide requirements and maintain war reserve stocks. **Combatant Commands** - Provide requirements and determine points of physical and accountability transfer of materiel.
CL V Ammunition Subclass: Conventional Ammunition Single Manager for Conventional Ammunition (SMCA) – Army DODD 5160.65	**SMCA** - Integrate wholesale conventional ammunition (specified items) logistics functions of Services to achieve efficiency and effectiveness. Coordinate transition of logistic support functions with Services. **Services** - Retain acquisition and logistics responsibilities not delegated to SMCA. Provide contingency requirements and receipt, storage, and issue requirements to SMCA. **Combatant Commands** - Coordinate support for military operations.
CL VI Personal Demand Items Title 10, USC Responsibility - Services	**Services** - Plan for, procure, and manage requirements and distribution of materiel. Provide supporting force structure. **Combatant Commands** - Coordinate support for military operations.
CL VII Major End Items Title 10, USC Responsibility - Services	**Services** - Plan for, procure, and manage requirements and distribution of materiel. Provide supporting force structure. **Combatant Commands** - Coordinate support for military operations.
CL VIII Medical Materiel EA – DLA DODD 5101.9	**EA** - Develop and implement acquisition and distribution strategies to support the medical materiel requirements identified by DOD components and CCDRs worldwide for peacetime, wartime, homeland defense and other contingencies. **Services** - Provide requirements and supporting force structure. **Combatant Commands** - Coordinate requirements and integrate EA supply chain recommendations.
CL IX Repair Parts Title 10, USC Responsibility - Services	**Services** - Plan for, procure, and manage requirements and distribution of materiel. Provide supporting force structure. **Combatant Commands** - Coordinate support for military operations.

Each class of materiel has an individual supply and distribution process, several of which we will explore in greater detail in later sections of this paper.

4.2 Transportation

How materiel is transported also has an impact on FOB sustainability, as any new system or solution still has to be transportable using current vehicle platforms and fit within the confines of existing transportation infrastructure and current operational practices.

In Iraq, where the land is relatively flat, the primary method of supply and resupply has been the truck convoy, usually with heavy contractor support. As of November 2007, 80 convoys were continuously traveling between Kuwait and Iraq (with 70% transporting fuel or water), exposing a critical vulnerability to Improvised Explosive Devices (IEDs) as they transported supplies from surrounding nations.[37]

The logistics of supply in Afghanistan, however, poses a different challenge. With a "road network much, much thinner than in Iraq", fewer airports, and a geography comprised mostly of mountains outside the deserts of Helmond province, the U.S. military in Afghanistan has remained "heavily dependent on supplies traveling the long, windy, and dangerous roads" or on resupply by air.[38] Both methods have often been unreliable in the mountain passes. The 20 foot "jingle trucks" used in convoys in Afghanistan flipped over in the mountains at such a rate that commanders have resorted to using dump trucks instead, and on a few occasions "heavy air drops, [Container Delivery Systems] (CDS) bundles, convoys, sling loads, and CH-47 pallets… all failed when getting material to build B-huts" in Afghanistan.[39]

Table 3, Transportation Information, provides a summary of the capacity of various transportation methods. For reference, a Force Provider module (Section 5.5 describes Force Provider in greater detail) for a 600 person base would require 54 sorties by C130, 24 sorties by C141, 12 sorties by C17, or 9 sorties by C5.[40]

Table 3. Transportation Information[41]

Air[1]			*Sea*		*Land*			
Aircraft	*Allow-able Cabin Load (lb)*	*Allow-able (cu ft)*	*Ship or Barge*	*Capacity (long ton)*	*Motor*	*Load (short ton per trip)*	*Rail*[2]	*Usable Cube (short ton)*
C-5A	204,000	18,368	7,029	2,207.8	2.5-ton	2.5	Well flatcar	50
C-141	90,200	7,024	7,028	1,131.2	5-ton	5.0	Medium flatcar	25
C-130	35,000	2,818	7,005	570	12-ton S&P	12.0	Small flatcar	12
C-17	167,000		231 A	585	22.5-ton flatbed	15.0	Boxcar	10
KC-10A	169,350	12,980	231 B	578	34-ton trailer	25.0	Coaches	40 troops
B-747	180,000		2,001	24-hour operation for troops/ 24 passenger	60-ton semitrailer	40.0	Sleepers	32 troops

[1]Estimates are for peacetime payload planning.
[2]Maximum length of a train is 40 cars; maximum net load is 400 tons or 1,000 troops.

4.3 Containers

Many classes of supply, as shown in Table 2, Military Classes of Supply, are brought into the theater in containers. If used properly, these containers can be converted from waste that must be disposed of into something useful, even potentially replacing other materiel that must be brought into theater.

According to U.S. Army FM 55-65, the types of containers include:

- **Interval Slingable Unit (ISU)**
  Certified for helicopter airlift and Air Mobility Command (AMC) aircraft. 463L pallet compatible and has a 10,000 pound capacity. Base measures 108"x88" and with heights ranging from 60-90."[42] 463L pallets have base dimensions of 108"x88" and can hold items 8 feet tall.

- **Milvan containers**
  20'x8'x8'; 41,300 pound capacity, 3,500 pound empty weight

- **Commercial shipping containers**
  Quadcon: Quadcons measure 82"x57"x96." According to FM 55-65, "it is a lockable, weatherproof, reusable, prefabricated container with a cargo capacity of 8,000 pounds. The Quadcon has a structural steel welded frame. Its top sides and door panels are made of plywood coated with a plastic laminate. The floor is [constructed] of high density plywood covered on both sides with sheet steel. Four Quadcons coupled together have the same dimensions as a standard 20-foot ISO [International Organization for Standardization] container."

The U.S. military increasingly relies on modular sets, like Force Provider, that can be deployed in a set number of containers.[43] The containers themselves, however, should be put to good use; some commanders in Iraq and Afghanistan have asked their contractors to turn shipping containers into offices, kitchens, and bathrooms.[44] One key to a sustainable FOB will be to fully utilize everything that enters the FOB, regardless of its original design, intent, or purpose. The steps to greater sustainability – fully utilizing all materiel at a FOB, reducing demand/consumption, minimizing waste through reuse of materiel, and reusing generated waste – will greatly contribute to lower costs and reduced casualties.

5 Facilities, Structures, and Construction

The third element in the sustainability equation is to understand and optimize facility design, engineering, and construction to enhance FOB sustainability

Highlights

- Depending on the size and sophistication of the FOB, a FOB can have a wide variety of different types of buildings
- The least costly construction method utilizes existing infrastructure as much as possible
- Tents are simple to transport and use but are not energy-efficient
- The cost of building material should factor into FOB design planning
- FOB sets, such as the Force Provider modules, have played a growing role in standardizing and simplifying field construction

Areas of Potential Future Research

- Design and deploy real-time energy demand management / smart grid systems
- Design and build more energy efficient structures. Adopt efficiency best practices in selecting construction material used, lighting technology, window technology, layout. Consider integration of renewable energy generation (e.g., thin-film solar) with structures
- Identify state-of-art solutions to improve the energy efficiency of structures. Spray foam insulation is a good starting point, but it also prevents re-use
- Design construction material supply chain to enhance sustainability
- Improve current base "sets", like U.S. Army Force Provider and USAF Harvest Falcon and Harvest Eagle

5.1 Types of Buildings

A typical Army FOB may include some or all of the following elements: life support areas, toilet/shower facilities, headquarters facilities, logistical support facilities, dining facilities, finance/personnel support, postal facilities, laundry collection and distribution point, aviation facilities, communication facilities, medical facilities, motor pool facilities, fuel storage facilities, hazardous waste collection facilities, ammunition supply points, training facilities, PX, morale-welfare-recreation (MWR) facilities, and detainee holding areas.[45]

Tallil Air Force Base (now transferred back to Iraqi control), for example, was originally built for 3,000 soldiers and had 22 barracks, 32 headquarters buildings, 3 dining facilities, 7 warehouses, 7 maintenance facilities, and 29 other support buildings such as a firehouse, jail, and mosque. Utilities included wastewater treatment plants, water treatment plant, and an electrical generation plant.[46] FOB Salerno had a gym, with exercise machines and big screen TVs, laundry, offices, hospital, morgue, and a church.[47] Other FOBs had variations of similar facilities and equipment.[48]

5.2 Types of Structures, Infrastructure

Pre-existing structures

The least costly and efficient manner of FOB construction utilizes existing structures to the greatest extent possible.[49] An USACE study states that current "construction of buildings in theater takes too long, costs too much, and ties up critical transportation resources."[50] In response, some commanders have used “mud-and-straw buildings built over packed dirt floors and topped with thatched wooden roofs” for offices, maintenance buildings, and clinics in Afghanistan and Iraq.[51]

Tents

Tents are the housing standard for the first soldiers in the field during an expeditionary campaign. As shown in the Table 4, Tents, General Purpose (GP) tents and Tent Extendable Modular Personnel (Temper) tents can vary in size. Temper tents include an aluminum frame with vinyl polyester duck cloth that is fire, mildew, and water resistant. Medium GP tents can house 12 people and be erected by 4 people in 1 hour, while large GP tents hold 22 people each and can be erected by 6 people in 1.5 hours.

Table 4. Tents[52]

Tier Level	*Bed-Down and Base Camp Living Standards*
Tier I	Simple tent setup without floor, nonpermanent
Tier II	Wooden floor, lights, pole-supported, 2 electrical outlets
Tier III	Slightly nicer wooded floor, 2/3 wooden wall structure with frame, more electrical outlets

Type	*Floor Area (sq ft)*	*Weight Packed (lb)*	*Volume Packed (cu ft)*
Tent, GP, small	198.9	163	26.2
Tent, GP, medium	512.0	534	33.0
Tent, GP, large	936.0	665	69.0
Tent, ext modular (temper)	640.0	2,192	200.0
Tent, maintenance, medium	640.0	1,798	62.0
Note. Operation Joint Endeavor living standard was 10 soldiers per GP medium.			

Using tents presents inevitable tradeoffs. Tents are relatively lightweight, do not incur substantial transportation costs, can be erected quickly, and could theoretically be reused in a future conflict. Trying to heat 20-cot sleeping tents or cool tents in 120 degree Iraqi summers, however, creates quality-of-life issues and is a tremendous drain on energy, power, and fuel.[53] One proposed solution to reduce the energy costs of heating/cooling tents has been to spray insulating foam on the tent surface, but that solution effectively turns a temporary tent into a permanent facility. Another area of current FOB sustainability research has been in evaluating the prospects of attaching solar panels to tents to mitigate the prodigious fuel requirements of managing tent climate.

Pre-engineered metal or fabric buildings

Pre-engineered buildings are usually used for maintenance facilities, as they require limited internal support columns and are relatively easy to construct. Navy estimates suggest that 10-12 people could assemble the 10,000 square feet K-Span structure in a day (see Figure 1, K-Span Structure).[54]

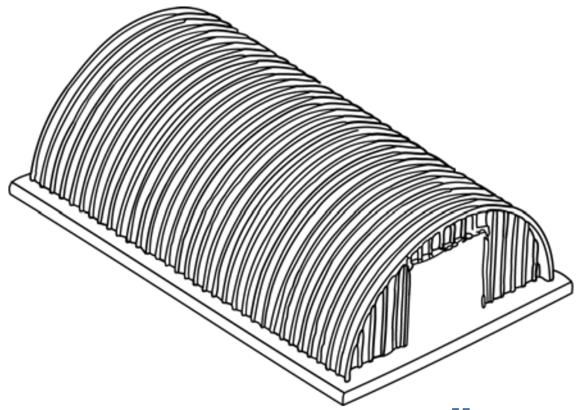


Figure 1. K-Span Structure[55]

According to the Army, a steel-based building "requires half as much material, half the construction time, less than a quarter the cargo space, and is 60% cheaper than wood buildings."[56] Other pre-engineered buildings include tension fabric buildings, such as the Universal Fabric Structures/clamshell structures.

Modular buildings, trailer units, assembled pre-fabricated buildings, or manufactured buildings

This category includes trailers and other Containerized Housing Units (CHU), which are shipping containers pre-fabricated into living quarters, offices, and other types of facilities. A typical office shipping container, for example, has six internet connections, shelves, and a desk. Such pre-fabricated/manufactured buildings offer cost savings, speed (as everything is pre-made), quality control, and ease of expansion and relocation.[57]

Constructing wood, steel, or Concrete Masonry Unit (CMU) framed and supported buildings

As described earlier, on-site construction allows for flexibility of design, but it can be costly, time-consuming, and require large quantities of Class IV supplies – luxuries in contingency operations.[58] CMU examples include B-huts and SEA huts. Both are wooden structures, with B-huts made of plywood and holding up to 8 people, and SEA huts "constructed of wood with a sheet vinyl floor, 5/8 inch gypsum walls and ceiling, flat latex paint, metal roof, precast concrete pilings, painted exterior."[59] There are 5 SEA huts in a Davidson configuration, for a total of 2,944 square feet of enclosed space.

Roads

Building roads requires substantial material. The Red Book requires asphalt roads, concrete turning pads, and gravel secondary roads, but gravel is often difficult to procure.[60] Procuring the 100,000 cubic meters of gravel for FOB Hammer, for example, required more time than originally scheduled.[61]

Furniture

Approved furniture for a soldier includes one bed, one mattress (single foam rubber with non-plastic shell), a one-foot locker, nail boards on walls of living areas, and locally built shelves made of plywood.[62]

5.3 FOB Footprint

The geographical footprint of an FOB can vary from encompassing a few acres to a few hundred acres to over 11,000 acres (18 square miles) for Al-Asad (including runways).

As shown in the Table 5, FOB Planning Factors, U.S. Army FM 3-34 suggests real estate acreage ranging from 16 to 350 acres for base camps for 500 to 10,000 soldiers, respectively. Troop housing would range from 0.91 acres to 18 acres across the spectrum. See Section 9 for detailed power requirements.

Table 5. FOB Planning Factors[63]

Table E-2. Summary table, base camp area, aggregate, and utilities requirements

Base Camp Size	*Real Estate Acre*	*Fine Aggregate (cu yd)*	*Course Aggregate (cu yd)*	*Potable Water (GPD)*	*Sewage (GPD)*	*Electricity (kW)*
500	16.0	450	620	12,500	8,750	182
1,500	51.4	1,700	2,485	37,500	26,250	486
3,000	104.7	3,320	4,820	75,000	52,500	988
10,000	350	11,200	16,066	250,000	175,000	3,293

Table E-10. Troop housing

Base Camp Size	*Officer (sq ft)*	*Enlisted (sq ft)*
500	11,000	28,800
1,500	33,000	86,400
3,000	66,000	172,800
10,000	220,000	576,000
Note. Assumes 20/80 officer to enlisted ratio; 110 sq ft per officer; 72 sq ft per enlisted		

Table E-6. Troop support facilities

Description	*Units*	*Criteria*	*500*	*1,500*	*3,000*	*10,000*
Dining facility	sq ft	sq ft per person varies by unit size	14.0	11.0	11.0	11.0
Fire station	sq ft	2.6 x size of vehicle + 90 sq ft	—	—	—	—
I/R facility	sq ft	250 sq ft military police + 50 sq ft per confinee	—	—	—	—
Bakery	sq ft	0.6 sq ft per person supported	300.0	900.0	1,800.00	6,000.0
Laundry	sq ft	sq ft per person varies by unit size	4.4	4.4	3.30	3.0
Dry cleaning	sq ft	sq ft per person varies by unit size	4.4	4.4	1.75	1.0
Chapel	sq ft	1.785 sq ft per person	893.0	2,678.0	5.55	17,850.0
Craft and hobby	sq ft	1.0 sq ft per person	500.0	1,500.0.0	3,000.00	10,000.0
Gymnasium	sq ft	3.3 sq ft per person	1,650.0	4,950.0	9,900.00	33,000.0
Library	sq ft	0.75 sq ft per person	375.0	1,125.0	2,250.00	7,500.0
Service club	sq ft	7.5 sq ft per NCO; 9.5 sq ft per officer	—	—	—	—
PX	sq ft	1.2 sq ft per person	600.0	1,800.0	3,600.00	12,000.0
Post Office	sq ft	sq ft per person varies by unit size	NA	NA	0.50	0.5
Theater	sq ft	sq ft per person varies by unit size	NA	NA	5.50	5.5

E-7. Examples of selected storage requirements and planning factors for base camps are addressed in tables E-7, E-8, and E-9.

Appendix E provides USACE planning factors, which differ from those in FM 3-34. Appendix F provides the planning factors for troop housing, with typical SEA hut and Temper tent configurations. Page 14 of the Red Book also provides additional information regarding specific FOB building square footage.

5.4 Construction

Class IV supplies include all construction raw material and fortification/barrier items such as lumber, wire, and sandbags.[64] Defense Logistics Agency (DLA) is the wholesale materiel manager and executes through Defense Supply Center Philadelphia (DSCP), with raw material procured as needed (although plywood and lumber is expensive in in-theater markets) and with a heavy emphasis on vendor support.[65]

Table 6, Construction Efforts, provides the estimated construction effort associated with FOBs of various sizes, and Appendix G provides a more detailed estimate of construction effort requirements for each component of a 500-man FOB.

Table 6. Construction Efforts[66]

Table E-1. Summary table, base camp engineer construction effort

Base Camp Size	*Short Tons*	*Equipment Hours*	*Man-Hours*			
			Horizontal	*Vertical*	*General*	*Total*
500	2,755	77	3,506	33,175	10,232	46,913
1,500	7,698	247	8,124	86,047	26,331	120,502
3,000	15,138	503	15,093	171,012	53,730	240,070
10,000	50,460	1,680	51,093	570,040	179,100	800,233

5.5 Sets (Force Provider, Harvest Falcon, Harvest Eagle)

As discussed earlier, FOB planning is often an exercise in expediency and adaptation. In order to make it easier to have uniform standards for all FOBs, the Army created the Army Force Provider (FP) concept. FP was developed as a standardized housing set that could be dropped into theater with everything needed to build a basecamp for 550 people. FP was also designed to work in conjunction with the AF's Harvest Falcon and Harvest Eagle sets for joint base operations. According to Congressional testimony, all of the Army's available FP modules have been deployed.[67]

Force Provider

A FP module includes tents with HVAC, command and control, showers, power generation, dining facility, medical, MWR, water and fuel storage, and wastewater collection. With FP, a FOB can be operational in 14 days using 50 people. The basic FP housing units are Temper tents, which include showers, latrines, and kitchen/dining facilities. As described in Section 5.2, a standard Temper tent (32'x20', or 640 sq ft) is comprised of 4 8'x20' Temper tent sections, can be erected by 4 people in 2 hours, and can house 12 people. When fully operational, 1 brigade sized module can serve 1,500 meals per day from 8 containerized kitchens, provide 3 showers per week per soldier from six shower units, and provide 20 gallons of water per day per soldier through four 20,000 gallon collapsible water tanks and 3 3,000 gallon ROWPUs.[68] A single FP module for 550 people is packaged in 103 Tricons (see Section 4.3, with three tricons equivalent to four quadcons), five 20-feet ISO containers, and 27 trailer mounted generators. FOB water, energy, and waste usage will be described in greater detail in later sections.

Harvest Falcon, Eagle

A bare base is comprised of a usable runway, taxi areas, and potable water. The Basic Expeditionary Airfield Resources (BEAR) program, with its Harvest Falcon (HF) and Harvest Eagle (HE) components, is the Air Force equivalent of the Army FP program. Both HF and HE are designed to be C130 transportable and together address transportation, housing, messing, aircraft maintenance, airfield lighting, power, water, sewage, heating, cooling, medical, and civil engineering needs.[69]

The Harvest Eagle platform includes a housekeeping and utility support set capable of supporting a 550 man AF FOB. With all relevant HE components, including housing, generators, kitchens, showers, laundry units, latrines, a HE module includes 75,000 units of supply, weighs 323 tons, requires 44,000 cubic feet of transportation volume, is packaged in 135 ISU containers, and is deployed using 8 C130 sorties with the 463L pallet system. The HE utilizes both the medium and large GP tents.[70]

The Harvest Falcon platform can support 1,100 people each and includes housekeeping, industrial operations, initial and follow-on flight line sets. Housekeeping includes billeting with heating, cooling, kitchen, showers, latrines, and generators. The HF also provides water, sewage, and electrical services. HF uses a standard Mobile Electric Power (MEP) 12 generator. Section 9.4 provides additional information on the energy usage associated with HF and HE modules. HF is deployed using 15 C130 sorties, using the 463L pallet system.

6 Force Protection

The fourth element in the sustainability equation is to optimize the sustainability of force protection measures by use of standard and nonstandard construction and supply materials

Highlights

- Successful force protection is vital to the survival of a FOB
- Using indigenous material and organic, creative solutions is key to a more sustainable FOB

Areas of Potential Future Research

- Design and develop new force protection technologies that are lighter, stronger, made of local material, and easier to build

Force protection is an essential element of FOB design, especially given the need for commanders to place FOBs near the local populace. Force protection measures include anti-personnel barriers, anti-vehicular barriers, structure protection, observation posts, entry control points, and tactical operations centers. Traditional force protection requires a significant amount of Class IV supplies, and using indigenous, organic, and creative solutions is key to a more sustainable FOB. As the 3rd Infantry Division discovered, the lack of Class IV materials in Baghdad forced the division to use "whatever was available for immediate force protection, including vehicles, Iraqi barbed wire, rubble, and earthen berms."[71]

More detailed information beyond what is presented here is available the *Joint Forward Operations Base (JFOB) Force Protection Handbook*.

6.1 Anti-Personnel / Vehicle Barriers

Anti-personnel barriers are mostly chain-linked and metal fences or concrete / CMU walls. At Balad (Iraq), for example, force protection was a mesh fence, with observation towers upgraded from wooden to concrete.[72] Even a triple strand concertina fence, however, can be time consuming. A 100 acre FOB would require 254 man hours just to fence with concertina.

Anti-vehicle barriers are usually rigid barriers or some type of temporary wall. Typical methods include:

- **Concrete barriers (Jersey, Alaska, Texas, Bitberg)**
  New Jersey barriers are 9' long x 3-3.5' high and weigh 400-600 pounds per linear foot. A heavy expanded mobility tactical truck with a crane could transport and place 10 at a time. These are apparently in short supply.[73] Texas barriers (Bremer Walls) are 12' high and Alaska barriers 20' high. One factory in Iraq was reportedly producing 50 tons of concrete a day to fill U.S. military contracts producing blast walls up to 18' high and weighing 2 tons each.[74]

- **Concrete or sand-filled oil drums**
  One FOB used 55 gallon oil drums – filled with rocks – as barriers when they ran out of HESCOs in Iraq, then used the drums later for fuel reservoirs or supports for 8' pickets.[75]

- **Concrete bollards or planters**

- **Steel or steel-reinforced concrete posts**

- **Sand or water-filled plastic vehicle barriers**

- **Earth-filled barriers (HESCO bastions, metal revetments)**
  See Section 6.2 for details regarding HESCO barriers.

6.2 Other Force Protection Measures

Other force protection measures include:

- **Sandbags**
  A standard sandbag is 4”x8”x16” and requires 0.3 cubic feet of sand; 100 bags would require 30 cubic feet (1.1 cubic yards) of sand. Twelve sandbags produce a wall 1’ high by 4’ long. Although filling sandbags is a time and manpower intensive effort, many FOBs – including FOB Brassfield-Mora and Camp Victory – use a waist or chest-high wall of sandbags for perimeter protection outside tents and porta-potties.[76]

- **HESCO Bastion Concertainer**
  HESCOs are pre-fabricated, collapsible wire mesh products lined with geotextile fabrics and filled with dirt to form barriers. Most HESCOs used in Iraq are either Mil 1 (4.5’x3.5’x32’) or Mil 2 (2’x2’x4’) (see Figure 2, HESCO, for picture of a HESCO). Company-sized FOBs needed, on average, 100 HESCOs for the perimeter, gates, and serpentines, but the difficulty was both delivering the HESCOs and obtaining sufficient material to fill them in an urban environment.[77] A pallet of seven Mil 1 units weighs 2,332 pounds, and delivering 1,000 meters of Mil 7 HESCOs required seven 20-ft jingle truck loads. A FOB commander in Afghanistan spent $25,000 on a front-end loader to fill 1,000 meters of HESCOs (2 weeks), while other FOBs used workers with shovels ($16,000, 2 weeks) to fill the same amount.[78]

- **Watchtower (wood or concrete)**
  FOB Danger had “tall concrete watchtowers hung with camouflage nets” and a “15 foot blast wall with coils of concertina wire on top.”[79]

- **Other**
  Other force protection measures included using the “existing regime’s flowerpots” or storm water piping (6 meters long x 1.5 meters in diameter).[80]

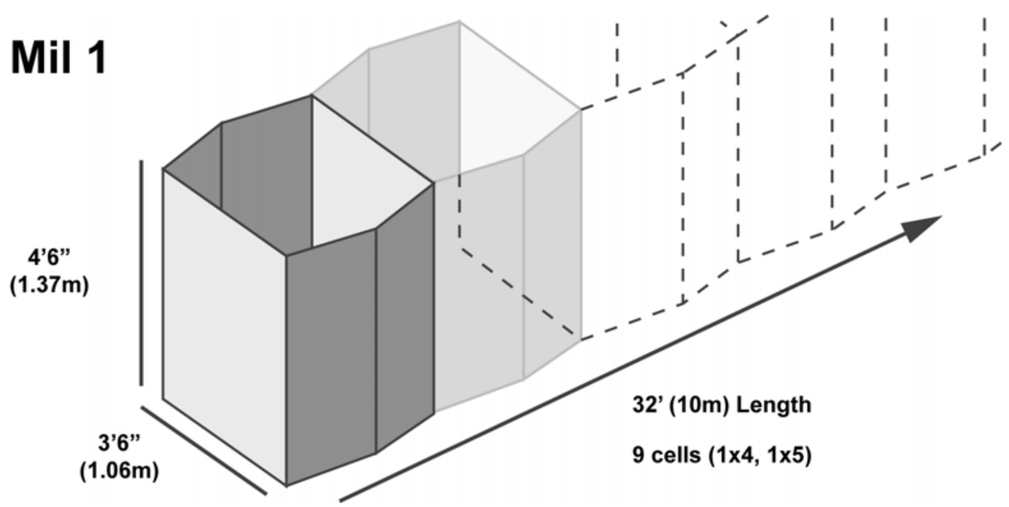


Figure 2. HESCO[81]

7 Food

The fifth element in the sustainability equation is to optimize food (Class I – Subsistence) sourcing and delivery and to minimize power consumption and waste generation

Highlights

- Rations are delivered to the tactical edge. Preparation of certain types of rations requires energy/power for cooking and/or refrigeration.
- Rations are a source of solid and human waste

Areas of Potential Future Research

- Design supply chain to reduce need for transportation without risking soldier safety
- Design rations to reduce packaging waste (e.g., biodegradable packaging)
- Design more energy-efficient field kitchens
- Design process to convert waste (including grease) to fuel, power, and energy

Redesigning food (Class I – Subsistence) input and output streams will be critical to developing a more sustainable FOB. Class I items, ranging from military rations to commercial food items, must be first procured and delivered to the tactical edge. Food preparation, depending on the type of ration, will also potentially require energy for cooking and refrigeration (Force Provider uses three 60 kilowatt (KW) generators for kitchen, dining, sanitation, and refrigeration).[82] Finally, Class I items are a source of both solid and human waste (75-90% of the solid waste in a base camp comes from food and packaging).[83]

7.1 Rations

A-Rations

A-Rations are meals prepared using fresh, refrigerated, or frozen foods. As a result, they are served in dining facilities, prepared in the field using field kitchens, or prepared at a fixed facility and delivered into the theater. A-Rations require food preparation personnel and equipment, plus refrigeration for the perishable foods. A-Rations include the Unitized Group Ration (UGR) – A Option (UGR-A), which includes all components for a 50 person meal (1,450 calories/meal) in one UGR-A module. One pallet has 12 modules (600 meals), and each module weighs 86.7 pounds and is 4.03 cubic feet.[84]

B-Rations

B-Rations are meals served using canned or preserved ingredients. B-Rations can be prepared in field kitchens and served in the field without refrigeration or freezer facilities. B-Rations include UGR – B Option (UGR-B), which also provide 50 meals (1,300 calories/meal) per module. Each pallet will have 8 modules (400 meals).[85]

UGR-Express

UGR – Express (UGR-E) is a “compact, self-contained module that provides a complete, hot meal for 18 warfighters” with no need for equipment or personnel. Each meal is equivalent to 1,300 calories.[86]

Meals, Ready-to-Eat

Meals, Ready-to-Eat have been staple rations for contingency operations. MREs consist of a full meal (1,250 calories) in a bag, packaged in cases of 12 MREs each (each case weighs 22 pounds). A pallet has 24 A cases and 24 B cases (different menus), for a total of 576 meals at 1,098 pounds/pallet.[87]

First Strike Ration

The First Strike Ration (FSR) is a compact ration used during the first 72 hours of conflict. Each FSR is sufficient food for one soldier for 24 hours (2,900 calories), and each case has 9 meals. 7 cases is therefore sufficient food for 63 soldiers for 24 hours. At 3.2 pounds, one FSR is also half the weight of 3 traditional MREs. The net weight for a case is 29 pounds, and at approximately 50 cases to a pallet, the net weight of a pallet is 1,442 pounds and includes 450 24-hour meals, or 1,350 equivalent MREs.[88]

UGR – Heat and Serve

UGR – Heat and Serve (UGR-H&S) is designed for wherever there are operational food service facilities during contingency operations. Each UGR-H&S module provides all components for a 50 person meal, unitized into 3 boxes. 2 modules (100 meals) occupy one tier of a 4-tiered pallet, so one pallet has 8 modules (or 400 meals). Each module averages 133 pounds for dinner, so the total pallet weight is 1,068 pounds on average. Appendix H provides representative weight and dimensional characteristics.[89]

7.2 Requirements

The basic subsistence requirements are based on Service-specific feeding plans designed to support the operational and tactical needs of the commander.[90] Together with DSCP, the Services then develop the Class I requirements for the theater, with considered factors including “anticipated missions, operational conditions, geographic locations, unit size, historical usage data, availability of food service personnel and equipment, and supporting food service facilities, storage, and transportation assets.”[91] As a result, soldiers at a more established, larger FOB can enjoy hot meals while soldiers at a more austere FOB eat MREs three times a day. Appendix I provides an example of a USAREUR contingency menu.

7.3 Distribution

In general, the Services design the distribution channels for Class I – Subsistence, which in turn determines the Class I inventory held in theater.[92] According to joint doctrine, operational rations (MREs, UGRs) are only stocked in limited quantities – managed by DSCP at DLA depots and contracted storage sites – based on contingency requirements.[93] The majority of Class I items for dining halls for dining facilities are supplied primarily by prime vendors who perform the “procurement, stocking, requisition processing, and physical distribution functions previously carried out by the DoD.”[94] Class A rations (including fresh meat, fruits, and vegetables) are not normally stocked, with produce procured as a Direct Vendor Delivery (DVD) item from CONUS/OCONUS sources and “market ready” items (e.g., baked goods, dairy) procured locally by the service, operational elements, or DSCP.[95] In practice, however, doctrine must be weighed against the cost and safety of procuring food locally. In Iraq, for example, all subsistence items were trucked in from outside the country, with no local sourcing.

As the Figure 3, Class I Distribution, illustrates, the physical distribution of Class I items, other than some operational rations, is mostly a commercial function through prime vendors. Appendix J provides sample distribution processes for Iraq and Afghanistan. According to one USMC study, 7 trucks in 2 convoys per week delivered UGR-Es, MREs, and UGR-H&Ss to FOBs in Afghanistan.[96]

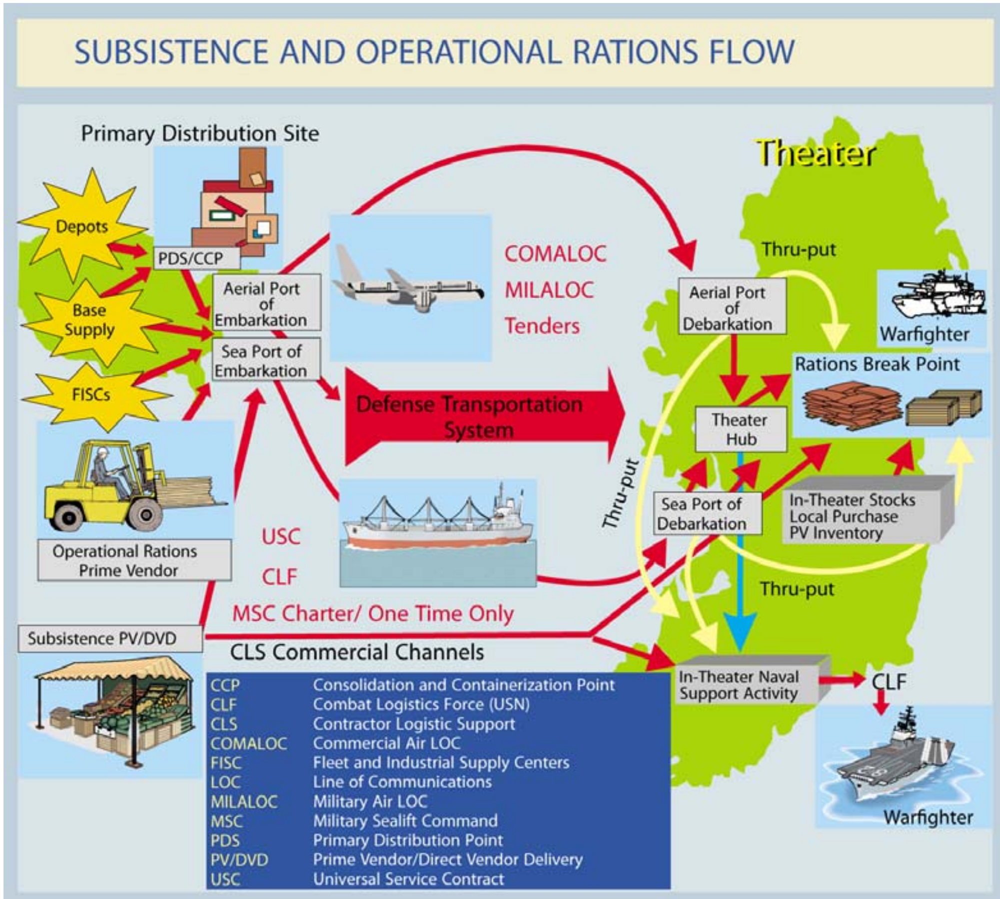


Figure 3. Class I Distribution[97]

7.4 Structures

The impact of subsistence on FOB sustainability also depends on the fuel and energy requirements of preparing food. Field facilities include:

- **Assault Kitchens**
  Kitchen, Company-Level Field Feeding-Enhanced (KCLFF-E) produces 150-250 meals/day.[98]
- **Mobile Kitchen Trailer**
  Introduced in the 1970s to replace the M1948 mess tent; still the primary Army field kitchen. Produces 250-350 meals/day.[99]
- **Containerized Kitchen**
  "Combination of existing military standard kitchen equipment and commercial components integrated into an expandable 8 foot by 8 foot by 20 foot container." Towed by a 5-ton cargo truck. Includes generator, environmental controls, and refrigerated storage. Provides 550-800 meals/day.[100]

8 Water and Wastewater

The sixth element in the sustainability equation is to optimize water acquisition, treatment, and wastewater disposal

Highlights

- Water is critical to expeditionary campaign success
- Water consumption and wastewater generation planning factors vary depending on geography, doctrine, Service, and command; reflects the flexibility required in developing sustainable FOBs
- Water can be procured from host-nation infrastructure (reservoirs, irrigation systems, municipal sources, and swimming pools), wells, natural surface sources, and bottled water
- Although officially the source of last resort according to U.S. military doctrine, bottled water is the principal source of drinking water at many FOBs throughout Afghanistan and Iraq. Not only is delivering bottled water expensive and dangerous, but the plastic bottles also become major sources of solid waste
- Wastewater treatment methods vary depending on size and sophistication of the FOB
- Burning waste, one disposal method at austere FOBs, can be hazardous to soldiers

Areas of Potential Future Research

- Identify ways to help promote sustainable behavior (e.g., less bottled water use, conservation)
- Develop more efficient, effective, and less energy-intensive water purifiers that produce tasteless water – both large scale and portable
- Develop strategy to expedite the certification of drinking water standards at FOBs
- Develop strategy to reduce bottled water consumption
- Design more sustainable wastewater treatment solutions
- Design process/technology to reuse wastewater

Water is paramount to expeditionary success. By far the largest shipments of supplies to the tactical edge in Afghanistan and Iraq have been to deliver water and fuel, with an emphasis on water. Supplying FOBs with water and removing wastewater are both significant challenges, but also represent significant opportunities to tackle a primary obstacle to more sustainable FOBs. This section will address 1) the amount of water required at FOBs, 2) current practices related to sourcing water, 3) the quantity of wastewater generated at FOBs, and 4) current practices related to wastewater disposal.

8.1 Water Consumption

Water is used for drinking, food preparation, laundering, centralized hygiene, Force Provider, and in a variety of buildings/structures.[101] Drinking, hygiene, and food preparation require potable water.[102] Water consumption factors vary depending on the source. A few examples:

- Table 5, FOB Planning Factors, provides estimates based on Army doctrine. A base camp would require 12,500 potable gallons of water daily (g/w/d) for 500 soldiers, 37,500 g/w/d for 1,500 soldiers, 75,000 g/w/d for 3,000 soldiers, and 250,000 g/w/d for 10,000 soldiers. That is equivalent to **25 g/w/d** per soldier.[103]

- Table 7, Water Consumption Planning Factors, provides Army general potable and non-potable water planning factors. Including the line items “individual”, “camp”, “sewage”, and “garbage” totals 16,500 g/w/d for a 500 man FOB, or **33 g/w/d** per soldier.[104]

Table 7. Water Consumption Planning Factors[105]

Consumer	*Rate of Consumption*	*Remarks*
Individual	3 to 6 GPD per man	—
Camp (initial with bath)	25 to 50 GPD per man	Include waterborne sewage
Vehicles (tactical)	1/2 to 1 GPD per vehicle	—
Support Facilities		
Hospital	200 GPD per bed	20-hour operation
QM laundry company	64,000 GPD	20-hour operation
Construction Equipment		
Road construction	10,000 G/km	Nonpotable, clean
Rock crusher	22,500 GPH	Nonpotable, clean
Concrete mixer	560/140 GPH	Nonpotable, clean
Other Considerations		
Sewage treatment requirements	2.5 gallons per man per day	Nonpotable, clean
Garbage (food waste)	2.5 gallons per man per day	Nonpotable, clean
Refuse (other waste)	—	Nonpotable, clean

- USAREUR (Blue Book) doctrine dictates **60** gallons of potable water daily per soldier.[106]
- Force Provider estimates that, for a 550 man FOB, latrines will require 2,700 g/w/d, laundry 5,200 g/w/d, showers 11,000 g/w/d, and food 1,925 g/w/d. Together, the 20,825 g/w/d results in a **38 g/w/d** estimate per soldier.[107]
- A brigade-sized cluster needs 66,000 g/w/d. A 3,000 man brigade would therefore imply **22 g/w/d** per soldier.[108]
- Al-Asad required 1.1 million g/w/d and generated 1.2 million g/w/d.[109] With 20,000 troops, that demand implies a **55 g/w/d** per soldier estimate.
- Personal accounts have placed consumption rates at 2 liters / soldier / hour during a mission, or around 12 liters – or approximately 3 gallons – per soldier per day (which mostly matches the Army estimates for individual consumption).[110]
- Typical homes consume **59.3 g/w/d** per person, with toilets (20.1 g/w/d per person), laundry (15 g/w/d per person), shower (13.3 g/w/d per person), and faucets (10.9 g/w/d per person).[111]
- Other data points: estimates range from **9** to **109 g/w/d** per soldier in the field, and the Army consumes 18.5 million g/w/d.[112]

8.2 Water Source and Treatment

Water for FOBs can be obtained in three primary ways:

1. Use existing, Host-Nation (HN) water distribution infrastructure
2. Distill, purify, or treat water from wells or surface sources (rivers, lakes)
3. Truck potable or bottled water into the FOB

Established doctrine calls for first evaluating host-nation sources to see if the water meets purity and quantity requirements, then to dig wells or use ROWPUs, Tactical Water Purification Systems (TWPS) or Light Weight Purifiers (LWP) to treat non-potable, in-theater water sources, and then only finally – if still necessary – to resort to trucking potable water or bottled water to the FOB.[113]

How water is actually obtained, however, will depend on the size, mission, and location of the FOB. At more established and larger FOBs, water can be more easily obtained from existing wells or current infrastructure, whereas in more austere locations, the primary sources of water are wells and bottled water trucked in from outside the theater. At FOB Hammer, "a water source was found, so it was no longer necessary to truck it in."[114] At Doa China, "conditions… are primitive: there is no running water, other than an electric pump which runs water from the deep well, connected to a hose."[115]

Existing Infrastructure

The "most efficient and successful sources of water during deployment often are the host nation support systems", including "reservoirs, [existing] manmade wells, fire hydrant systems, irrigation systems, water plants, water towers, quarries, and swimming pools."[116] During Operation Iraqi Freedom (OIF), the 3rd Armored Calvary Regiment tapped into Al-Asad's fire hydrants, filled a 400,000 gallon pool, and then used 4 ROWPUs to create 50,000-70,000 g/w/d.[117] Using existing infrastructure, however, creates potential political and health liabilities (unreliable chlorine residual, leaky plumbing, less stringent water standards).[118]

Wells and Natural Sources

Digging wells and purifying water from natural sources are alternatives to tapping into existing HN infrastructure. Red Horse, for example, drilled wells at FOB Sharana that pumped 165,000 g/w/d, while canal water was run through ROWPUs and then bottled on-site at Balad.[119] Studies have explored potentially obtaining water from water vapor, rain, wastewater, urine, perspiration, and condensation of water vapor in exhaust.[120]

Bottled Water

Although officially the source of last resort, bottled water has become a standard source of water for FOBs of all sizes. While there are benefits to using bottled water as the primary water source, there are also significant cost, supply, and waste problems associated with using bottled water.

First, the benefits of using bottled water:

- There remains a psychological impression that bottled water is safer and cleaner, although bacteria can flourish in plastic bottles in OIF/Operation Enduring Freedom (OEF) theater heat
- Easy to pack and carry on missions
- More convenient to use, no washing required (as with CamelBaks and other similar products)
- Easily accessible, with stacked pallets throughout a FOB
- Builds political capital as soldiers hand bottled water to civilians during humanitarian missions

The consequences of using bottled water:

- Costly. Estimates range from $4.78 to $15.30 to over $50.00 per gallon to deliver water to the tactical edge.[121]
- Huge supply requirement. Technically, bottled water follows the Class I distribution network. A USMC Energy Assessment team found that a battalion-sized FOB had, on a weekly basis, 14

trucks delivering water and 2 trucks delivering fuel.[122] As the USMC Commandant said,

"Eighty – almost 90 percent of what we deliver on a daily basis today in Afghanistan is either water or fuel. And I don't know how many times I've seen these 40-foot trucks hauling water, driving across the bridge and the river to get to where they're going. I hope I make a point to you in that. We're carrying water hundreds of miles to get to where our troops are. By the way, it doesn't taste very good after spending – you know, sort of semi-boiled in 130-degree heat. But, nevertheless, we know it's pure; we know it's clean. And we're paying exorbitant prices for that kind of delivery. And, again, I just have to think that we can do better."[123]

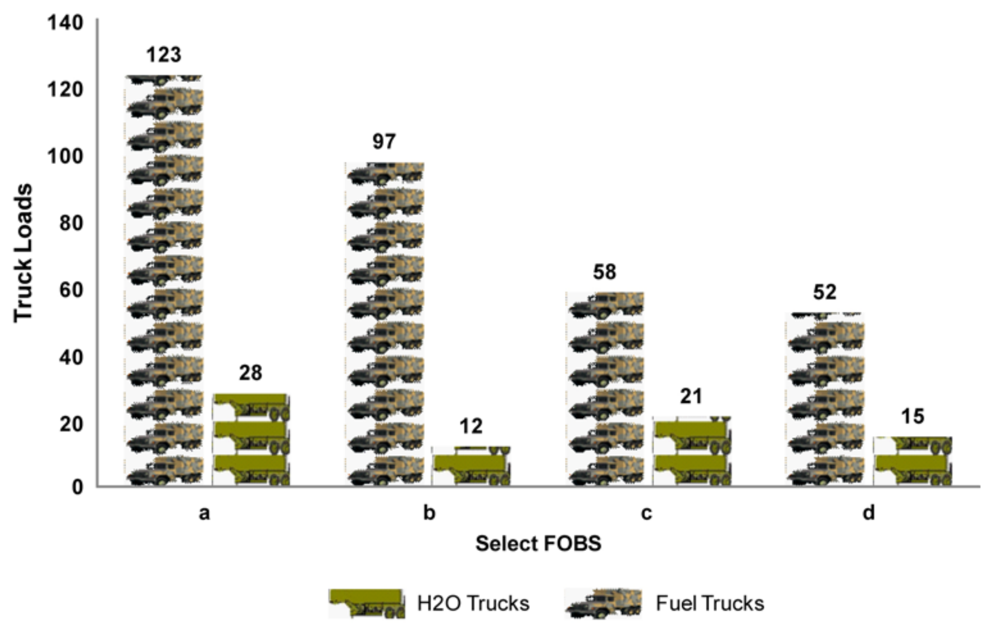


Figure 4. Bottled Water[124]

- Significant source of solid waste. Soldiers have described finishing half a bottle, tossing the rest, and picking up a new bottle from the mountain of bottled water. Waste is generated even before the bottled water gets to the FOB, as the bottled water has to be shipped in shrink-wrapped pallets. Half of all the bottled water containers are then discarded because the shrink-wrap tears, and then another third are discarded because of shelf-life and expiration issues. The last section in this report will be dedicated to evaluating solid waste at FOBs.[125]

8.3 Wastewater Source and Quantity

FM 8-10-15 categorizes waste into 5 groups: general (including solid) waste, hazardous waste, medical waste, medical waste, human waste, and wastewater.[126] This section will address the last two – human waste and wastewater. These include graywater, including water with low levels of microbial contamination (and therefore the easiest to treat and re-use) from laundries, wash racks, and showers, and blackwater from FOB toilet facilities.[127] As with water consumption, estimates can vary:

- Force Provider, for a 600 man base, generates 5,200 gallons of graywater per day (g/gw/d) from its containerized batch laundry system, 11,000 g/gw/d from its containerized shower system, and 1,375 g/gw/d from its food service facility. That totals to 17,575 g/gw/d (**29.3 g/gw/d** per person), which is slightly different than other studies with 19,000 g/gw/d (**32.0 g/gw/d** per person).[128] FP also generates an estimated 3,465 gallons of blackwater per day (g/bw/d), or approximately **5.8 g/bw/d.**[129] Together, these estimates suggest approximately 21,000 to 22,500 gallons of waste water generated each day (g/ww/d), or **35 – 37 g/ww/d** per person.

- Red Book estimates that each FP-sized FOB will generate 30,000 g/ww/d (**50 g/ww/d** per person), and another study puts FP wastewater generation at 20,000 g/ww/d (**33 g/ww/d** per person).[130]
- Other estimates have ranges from **1.5 – 44 g/ww/d** per person, and FM 3-34 has sewage estimates of 8,750 gallons/day for a 500 man base (**17.5 g/d** per person), 26,250 g/d for a 1,500 man base, 52,500 g/d for a 3,000 man base, and 175,000 g/d for a 10,000 man base.[131]
- On average, 15% of all wastewater is blackwater, with graywater as the balance

8.4 Wastewater Treatment

Measures used to handle wastewater will differ according to FOB population, general standards, contractor services, and location. As a general rule, the smaller and more austere the FOB, the more primitive the methods employed for managing wastewater.[132] As FOBs mature and take on a more enduring role, however, methods will evolve as well, with more rudimentary systems giving way to chemical latrines, storage/septic tanks, and ultimately to conventional treatment systems. Camp Bondsteel in Kosovo, for example, first utilized truck collection of waste (and disposal in a pit), then built a four-cell aerated lagoon, and then built a conventional wastewater treatment plant.[133]

Burn out latrines

Using burn out latrines is perhaps the most rudimentary field sanitation method and often standard operating procedure at FOBs on the tactical edge. An oil drum is cut in half and a wooden seat added to the top. Vehicle fuel is then added to the human waste in the oil drum and set on fire. While burn out latrines are easily constructed, have a minimal geographic footprint, and minimize the remaining waste, they are unsafe, generate quality of life issues for soldiers, creates air pollution, wastes fuel, and requires separate facilities for liquid waste (urinal pipes, or “piss tubes”).

Chemical latrines (Porta-Johns)

These self-contained toilets require minimal construction effort and can be located anywhere, but most require contractors to service and the waste must be removed to a sanitary landfill site. These considerations require that the FOB be relatively more established, with sufficient manpower to manage the in and outflow of contractors servicing the chemical latrines.

Sewerage lagoons

These lagoons can be used to treat and dispose of black and graywater, avoiding the need for contractors to remove waste. Since they should be built away from housing to avoid wind or groundwater contamination, sewerage lagoons require that the FOB be large enough to accommodate both the lagoon and a buffer zone. These lagoons can also be restoration problems in the future.

Septic system and leach fields

These systems also allow for black and graywater disposal, but require both significant amounts of land and a distribution system; they are better suited for more established FOBs.

Wastewater treatment facility

Wastewater treatment plants are on the opposite side of the spectrum from burn out latrines, and are therefore used in some of the relatively larger FOBs. There is a limited ability to construct and operate wastewater treatment plants during contingency operations, however, and not all theaters of war provide easy access to a HN municipal wastewater treatment plant. They are also expensive and are capped by design capacity. Eagle Base in Bosnia originally had a 500 person capacity wastewater treatment plant, but had to build a new $1 million plant when 3,000 U.S. troops arrived.[134]

Conservation / reclamation

A "deployable and easy-to-use water reclamation station, which transforms wastewater into reusable water within the base, would improve the base environment, security, soldiers' health, stewardship of foreign lands and concurrently reduce cost and fresh water demand from off-base sources."[135]

9 Fuel, Power, and Energy

The seventh element in the sustainability equation is to minimize fuel and energy demand at FOBs

Highlights

- Fuel consumption has grown substantially since the Vietnam War, a consequence of technology and increasing complexity
- Fuel distribution faces IED attacks in Iraq and impassable terrain in Afghanistan
- The fully burdened cost of fuel can range to hundreds of dollars per gallon of delivered fuel
- FOB fuel usage estimates vary, depending on the size and primary mission of the FOB
- Support operations are a significant source of battlefield fuel demand
- Problems at FOBs: inefficient generators, excess generation, inefficient buildings
- Batteries represent a significant constraint on individual fighting capability

Areas of Potential Future Research

- Design more energy-efficient buildings that require less electricity
- Design energy supply/demand management software; run generators to meet supply
- Ensure compatibility between generators and appliances
- Develop training strategy/curriculum for interconnected power systems
- Design efficient, next generation power generators
- Design renewable energy generators specifically for FOBs
- Design methods to produce and use alternative fuels
- Reduce battery weight for individual soldiers
- Design supply strategy to streamline fuel distribution
- Design fuel recycling program

Fuel is of paramount concern to deployed troops. Bulk fuel is propulsion fuel for the aircraft, ships, and vehicles that sustain the warfighting capability on the tactical edge and what runs the Heating, Ventilating, and Air Conditioning (HVAC) systems that cool the tents in hot Iraqi summers.[136] But the importance of fuel and energy is overshadowed by the costs incurred while transporting fuel, with the costs paid for in dollars and lives. Even batteries are a literal burden on the shoulders of our soldiers.

This section will provide a snapshot of fuel and energy distribution and consumption in theater, at FOBs, and at the individual soldier level. The principal supply class evaluated will be Class III materiel.

9.1 General Statistics

Some general statistics highlight the growing dependence on fuel to sustain war. As of 2007, fuel consumption was at 22 gallons per soldier per day for OEF and OIF, which represented a 175% increase in per capita consumption since Vietnam.[137] Much of that growth has been fueled by military technology and increasing complexity. A Marine infantry battalion, for example, had 55 armored Humvees in 2008, compared to 32 canvas Humvees in 2001.[138] That same battalion had 1,220 radio sets in 2008, compared to 175 in 2001.[139] In FY 2006, the U.S. Army used 412 million gallons of jet fuel/mobility fuel ($940 million), 59 million gallons of diesel ($123 million), 20 million gallons of gasoline ($45 million), and 330,000 gallons of biodiesel ($775,000).[140] By 2008, the DoD was supplying 68 million gallons of fuel per month to just support OEF and OIF, or over 2 million gallons per day.[141]

9.2 Distribution and Cost

The overall distribution/supply chain for fuel is fairly straightforward. The Joint Petroleum Office for the theater-level command sets the fuel consumption and primary planning requirements based on current and future operations. DLA is the materiel manager, and the Defense Energy Support Center (DESC) arranges the contracts and procures the fuel from military or commercial sources as "close to the customer as possible."[142] DESC then coordinates with U.S. Transportation Command (USTRANSCOM) or otherwise arranges transport of the fuel outside the joint operating area by existing HN assets, pipeline, ocean tankers, barges, trucks, or rail.[143] Once fuel is delivered to a hub in theater, DESC hands off responsibility to the Service elements to distribute the fuel to FOBs on the tactical edge.

Table 8. Responsibilities[144]

Table 1: Responsibilities for Bulk Petroleum in Support of Military Operations

Office	Responsibilities
Under Secretary of Defense for Acquisition, Technology and Logistics	Establish policies for management of bulk petroleum stocks and facilities and provide guidance to other DOD agencies, the Joint Staff, and the military services.
Deputy Under Secretary of Defense (Logistics and Materiel Readiness)	Serve as the central administrator for energy management and has integrated materiel management oversight responsibility for fuel products.[a]
Under Secretary of Defense (Comptroller)	In coordination with the Under Secretary of Defense for Acquisition, Technology and Logistics, establish financial policies and guidance for management of bulk petroleum products.
Chairman, Joint Chiefs of Staff	Primarily focuses on wartime support; coordinate with DOD, the military services, and the combatant commands to resolve petroleum issues.
Joint Staff J-4	Act as primary agent of the Chairman of the Joint Chiefs of Staff for all bulk petroleum matters.
Commander, U.S. Transportation Command	Develop long-range plans for petroleum support of the inter-theater mission and contingency operations worldwide.
Combatant Commanders	Ensure fuel support is provided to combat forces to accomplish those missions assigned by the President and the Secretary of Defense.
Director, Defense Logistics Agency	Meet the petroleum support requirements of the combatant commands and the military services.
Director, Defense Energy Support Center	Carry out functional responsibilities of the Director, Defense Logistics Agency to include procurement, ownership, quality surveillance, accountability, budgeting, and non-tactical distribution of bulk petroleum stocks to the point-of-sale.
Military Services	Provide petroleum support to its service and other services; is responsible for further distribution and management of fuel once it has been delivered to the service.

Source: Joint Chiefs of Staff Joint Publication 4-03.

In practice, however, fuel distribution is far less straightforward as the U.S. military must balance safety and diversification of sources with speed and cost. Fuel is delivered to Iraq through Kuwait, Jordan, and Turkey and to Afghanistan through the northern Central Asian states and Pakistan. In Iraq, the long fuel convoys have been the targets of significant IED attacks. In Afghanistan, bringing fuel by the northern routes involves shipping refined oil products thousands of miles by rail, truck, barge, or pipeline from Turkmenistan or Azerbaijan.[145] After the fuel arrives at the Afghan border after 10 days, the fuel is loaded onto trucks for the additional 2-4 days it takes to reach the military's fuel hubs.[146] Even then, the military is confronted by a host of challenges including "mountainous terrain with inadequate or nonexistent road networks, harsh weather in the winter months" and insurgent activity, thereby requiring the occasional costly airdrop. In Afghanistan, one commander first received 5-gallon fuel cans on CH-47 pallets, then 50 gallon drums, and finally installed 20,000 gallon fuel blivets on site and used locally contracted fuel trucks to fill them with 5-6 months worth of fuel before winter.[147]

The concept of incorporating the "fully burdened cost of fuel" into military calculations has been a contentious issue, with disagreements on what to include and how to calculate the component pieces.

As a result, the estimates of delivering fuel to the tactical edge vary significantly depending on the source. The USMC Energy Assessment team calculated the contractor delivered fuel to Camp Leatherneck in Afghanistan at $6.39 per gallon, and $11.70 per gallon to deliver the fuel to the tactical edge (FOB Dwyer, 50 kilometers from Camp Leatherneck).[148] An earlier estimate puts FY 02 standard DESC fuel price at $1.34 per gallon, a "true cost" of USAF tanker-delivered fuel at $17.50 per gallon, and "hundreds of dollars per gallon for Army forces deep in the battlespace."[149] A DoD estimate by Steve Siegel presented in a Deloitte report spans the gap, with the fully burdened cost of fuel estimated to be $45 per gallon (see Figure 5, Fully Burdened Cost of Fuel).[150]

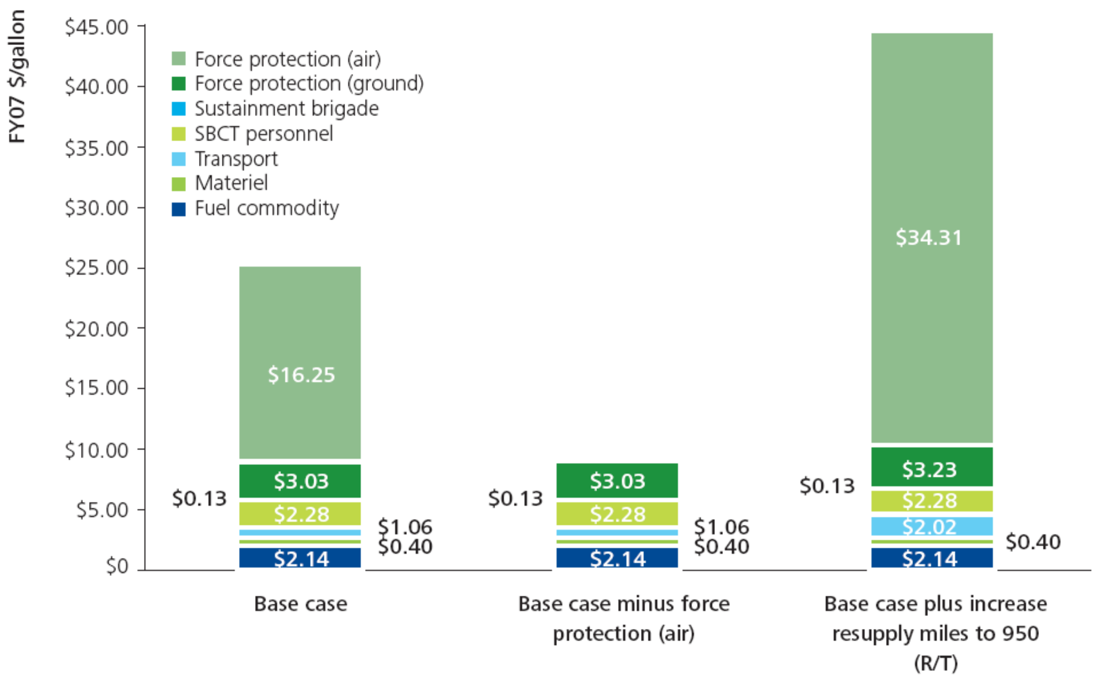


Figure 5. Fully Burdened Cost of Fuel [151]

9.3 FOB Fuel Usage

Fuel usage at FOBs will vary with size, location, and mission. FOBs with an aviation component will obviously consume more fuel than one without aviation. FOBs at the tactical edge, where there is less energy and electricity demand, consume less fuel than a main base with TVs and HVAC systems.[152] Fuel consumption estimates include:

- General Wald: FOBs consume 300 g/d, although without knowing what size the FOB is, this estimate seems to be on the lower end in comparison to the other estimates.[153]
- General Conway: U.S. Army brigade (3,500-4,000 soldiers) needs 10,000 gallons daily (**2.5-2.8 g/d/soldier**). Camp Lemonier, Djibouti, in an energy audit in 2006 had 2,500 soldiers and averaged 10,000 gallons of diesel per day (**4 g/d/soldier**).[154] In June 2008, that had increased to 333,191 gallons for base support, which equates to 11,106 gallons/day, or **4.4 g/d/soldier**.

- Army doctrine (FM 3-34) requires 3,200 barrels of diesel storage for a 10,000 man base, with a stock objective of 8 days. 3,200 barrels is equal to 134,400 gallons, so over 8 days, that implies 16,800 g/d, or **1.7 g/d/person**.[155]
- Camp Leatherneck required 36,740 gallons/day (**3.7 g/d/soldier**, assuming ~10,000 troops at Leatherneck), of which 15,431 gallons (42%) were for generators; HVAC required 7,406 gallons/day.[156]
- Jugroom, a platoon sized FOB in Afghanistan, required only 25 g/d of JP-8 with a 3 KW max load (or **1 g/d/soldier** for a 25 man base).[157] Another platoon sized FOB in Afghanistan used 50 g/d, or **1-2 g/d/soldier**.[158]
- General Conway: 15,000 man USMC expeditionary brigade with an aviation component to consume 500,000 g/d in attack plans (**33 g/d/soldier**).[159] 73% of that, however, was for aviation and only 17% to logisticians (85,000 g/d), or **5.6 g/d/soldier**.[160]
- Force Provider for 600 soldiers requires 20,000 gallons for every 3 days, or **11 g/d/soldier**.[161] Another FP estimate had 3 FP modules consuming 6,700 g/d, or **3.72 g/d/soldier**.
- A base for 1,100 people using HF housekeeping, industrial operations, and initial and follow-on flightline sets will consume 4,880 g/d, or 146,400 gallons in a month (**4.4 g/d/soldier**).[162] Appendix M provides an overview a study of HF energy and fuel demand.

Fuel Use Distribution

The allocation of fuel used for different purposes reflects the mission and location of the FOB. For Marine Expeditionary Brigade (MEB) A, fuel use in August 2009 was 46% for aviation, 32% for power generation, and 22% other.[163] At COB Adder, 78% of the 1,602,013 gallons of fuel consumed in June 2008 was for base support, while only 13% of the 7,072,136 gallons consumed at Bagram Air Field during the same time was for base support.[164] For Air Force HF sets, environmental control accounts for 59% of the energy requirement for a 1,100 man base.[165]

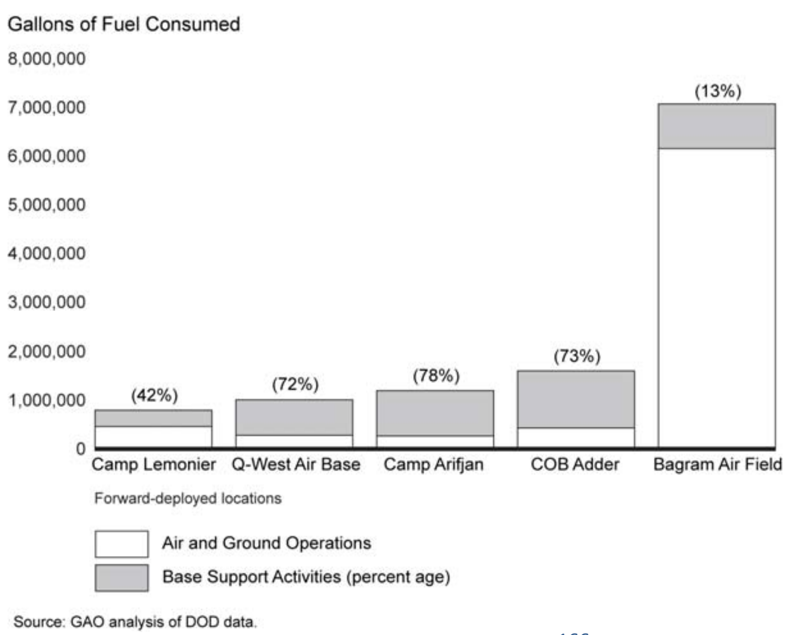


Figure 6. Fuel Consumption[166]

Appendix K provides fuel consumption details for Camp Lemonier, Q-West Air Base, Camp Arifjan, COB Adder, and Bagram Air Field.

9.4 Power and Electricity Generation

At many FOBs, support operations to power the equipment, systems, and infrastructure represent a significant source of battlefield fuel demand, with the water heater for a field kitchen requiring more fuel than the AH-64D Apache attack helicopter.[167] With 1/3 of the Army's total wartime fuel used for running electric generators, reducing electricity and energy demand at FOBs can result in significant fuel savings.[168] With no existing emphasis on energy efficiency at most forward locations, insulating 9 million sq ft of temporary structures saved 77,000 to 180,000 g/d, equivalent to 13 to 26 truckloads of fuel.[169]

Amount of Power Needed

Estimates of energy demand, as always, vary depending on the size, location, and mission of the FOB:

- A FP module requires 1.1 MW of continuous power or about **2 KW/soldier**.[170] If latrines (38 KW), laundry (100 KW), showers (55 KW), and food (120 KW) total 313 KW, then the remaining 787 KW, if used entirely for electricity generation, is 72% of the total FOB demand.
- At Camp Leatherneck, 5 MW of average energy demand equates to approximately **0.5 KW/soldier**, assuming 10,000 soldiers.[171]
- A "platoon-sized FOB, running satellite internet systems, lights, computers, and battery chargers, requires an [average] total of 20 KW", which for 25-50 soldiers, equals **0.5 to 0.8 KW/soldier**. This excludes heating and cooling, which is a significant demand source.[172]
- Army Doctrine has an estimate of **0.32-0.36 KW/soldier** (most likely continuous, not peak).[173]
- A HF 1,100 set has a peak demand of 3,878 KW, or **3.5 KW/soldier**.[174]

The Problems

There are three significant problems with how electricity is generated at FOBs.

- FOB structures are inefficient, with significant demand placed on generators to power systems to heat or cool tents with no insulation.
- The supply of power generated far exceeds demand at most FOBs. At Camp Leatherneck, the 5 MW of demand is met by 19 MW of capacity, with 196 generators running at 30% capacity and consuming 15,431 gallons of fuel per day.[175]
- The generators and appliances are inefficient. One commander complained that only 50% of the heaters worked, with another commander mentioned that as little as 3% of the generators available were running since the military generators wouldn't always work with the commercial HVAC systems they had to procure.[176]

Source of Power

Just as wastewater treatment methods are more sophisticated at larger and more established FOBs, the source of electricity and power at FOBs follow the same evolutionary path.

- At the smallest, most austere FOBs, there are no generators.

- At austere FOBs with some energy demand, there are distributed generators.[177] Distributed generators should not be loaded at less than 50%, according to doctrine.[178]
- "As the battlefield solidifies and the AO matures, the consolidation of small unit power systems is desirable." Small FOBs "should construct central power plants capable of supporting 125% of camp maximum demand load."[179]
- As the FOBs get larger, there is a greater need for centralized, contracted power plants with interconnected distribution systems. At Balad, for example, the Air Force had a generator farm with several 40 ft Milvans holding Caterpillar 12 cylinder generators that ran on diesel.[180]
- Finally, FOBs can tap into the HN commercial utility grid, with all the ramifications of potential political liability and infrastructure weaknesses.

Types of Generators

The following presents several different types of military generators. Despite the seemingly exhaustive list of generators available, however, OEF/OIF saw a considerable reliance on commercial generators.

- **Deployable Power Generation and Distribution Systems (DPGDS)**
  DPGDS meant to replace the 750 KW sets, as DPGDS units are 25% lighter, 15% more fuel efficient, and are more reliable.[181] Power Unit (PU) – the MEP 810A or B Model – has two Caterpillar 460 KW sets capable of delivering 920 KW at 4,160 volts (v), and 50/60 hertz (HZ). MEP 810A can be transported via C130.
- **Mobile Electric Power / Prime Power**
  MEP generators range from 0.5 KW to 920 KW, including the 750 KW MEP 012A Prime Power Units. The MEP 012A weighs 25,000 pounds, measures 241"x96"x101", and consumes 55 gallons of fuel per hour. Uses liquid cooled, turbocharged V12 diesel (Cummins KTA-38). The MEP 208A is also a 750 KW generator, and the Air Force also uses the MEP 805 (30 KW, 3006 lbs, 2.43 gallons/hr), 806 (60 KW, 4063 lbs, 4.51 g/hr), and 807 (100 KW, 6100 lbs, 7.85 g/hr).[182]
- **Multi-Unit**
  Multi-unit 4.5 MW Electro Motive Division (EMD) plants – 3 generators each capable of producing 1.5 MW at 4,160 VAC at 60 Hertz
- **Tactical Quiet Generators (TQG)**
  Began being fielded in 1993 and now provides 82% of Army tactical power needs. Developed for greater mobility, survivability, and reduced acoustic signatures. Appendix L provides a list of TQG model types.
- **Advanced Medium Size Mobile Power Sources (AMMPS)**
  A 3 KW TQG weighs 325 pounds, but even then may be overpowered for the load, so a new generation of generators will be developed and fielded in the near future.[183]

9.5 Individual Soldier

Not only is energy demand a burden for FOBs, but the weights of batteries required in the fight poses an effectiveness and quality-of-life constraint directly on our soldiers. One study, for example, estimates that 15-20% of a soldier's 70-90 pound pack is batteries.[184] Another study finds that a soldier must often change batteries 2-3 times during a 12-18 hour mission, meaning that a "rifle platoon's 5 day mission can require 889 batteries totaling 160 pounds… at an estimated cost of $13,000."[185]

10 Solid Waste

The eighth element in the sustainability equation is to minimize generation and optimize disposal of solid waste

Highlights

- Accumulation of solid waste can become an environmental, health, and political liability
- Plastic water bottles, wood, and food packaging are three significant sources of waste. The wood from containers and pallets should be re-used at the FOB in some other capacity
- Solid waste generation rates differ depending on the characterization study in question
- There is a hierarchy of solid waste disposal methods, from burning waste to hiring contractors to haul waste from the FOB. Burning is prevalent in Afghanistan.

Areas of Potential Future Research

- Design more sustainable and safer disposal technologies/practices
- Develop recycling program; identify opportunities to re-use solid waste
- Design more efficient and reliable incinerators
- Develop safe treatment method for ash generated after burning

Managing solid waste at FOBs has always plagued military commanders. At the rate at which solid waste is accumulated, it can limit warfighting effectiveness or become an environmental, health, and political liability. This section will 1) describe some of the primary sources of solid waste, 2) provide an overview of several characterization studies that have been prepared to date, and 3) highlight principal practices related to the treatment and disposal of solid waste.

10.1 Select Sources of Solid Waste

A significant portion of a FOB's solid waste stream is comprised of packaging materials (cardboard, paper, plastic) and food waste.[186] Packaging for small arms ammunition (SAA) is also a significant source of waste since OEF and OIF are SAA driven.

Plastic

As described earlier, bottled water has become a standard source of drinking water during contingency operations. Some FOBs receive bottled water deliveries through standard Class I distribution channels, while others bottle purified water on-site. Regardless of source, the amount of bottled water consumed poses a significant challenge. Eagle Base, for example, "generates the same types of waste as a small community, with the exception of an extraordinary large volume of plastic water bottles." Not only was the cost sufficient to prompt a transition to using a local water source, but the plastic water bottles were problematic due to the sheer volume and "to the noxious fumes they create when burned in an air curtain destructor", a standard disposal method.[187]

Wood

Wood, too, is a significant source of solid waste. When the solid waste stream at FOBs is compared to municipal waste, "the most obvious difference is the much larger percentage of wood in base camp waste. Virtually everything that is shipped to a base camp arrives on wooden pallets or in wooden crates and boxes."[188] As with the discussion regarding containerization in Section 4.3, wood waste is another potential area of research in identifying opportunities, if not to curtail the incoming stream, then to at least maximize the use of wood for other constructive purposes at the FOB.

Food

As mentioned earlier, food represents 75-90% of the solid waste produced at a FOB.[189] The two sources of this waste are 1) packaging and 2) food waste, with the relative volume of the two sources dependent on the type of FOB. At more austere FOBs, where the primary food source is the MRE, ration packaging is a primary source of food-related solid waste. Figure 7, MRE and UGR H&S Packaging, provides an overview of the packaging of MREs and UGR H&Ss.

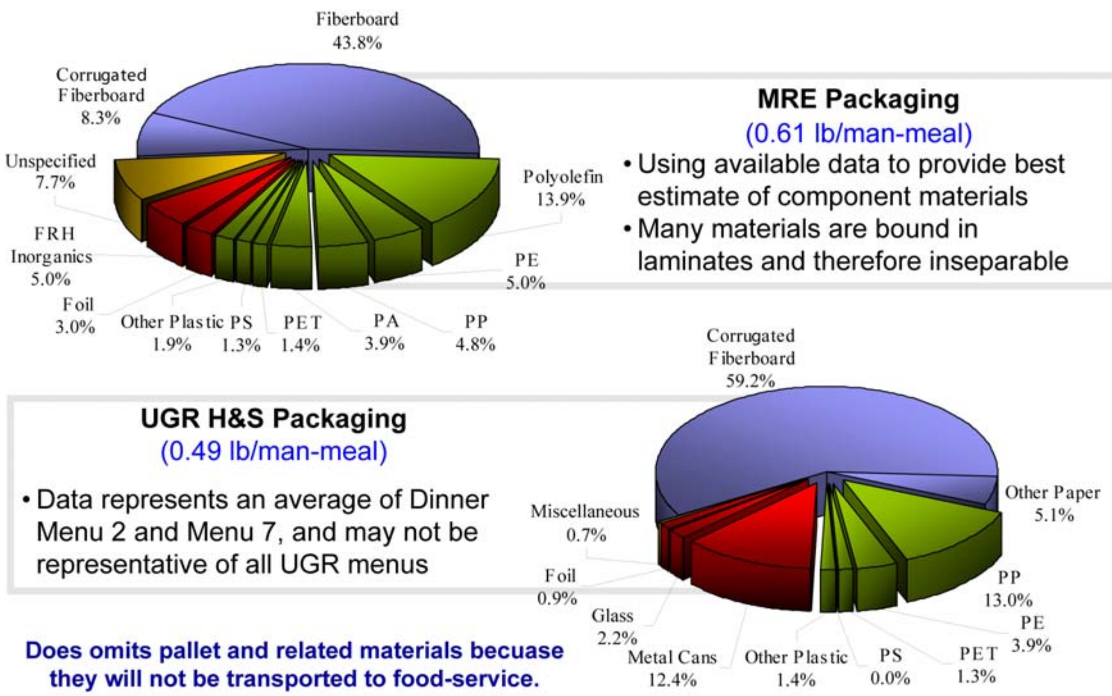


Figure 7. MRE and UGR H&S Packaging[190]

As "base camp and supply route security issues are resolved to the point that service contractors can service the base camp", "the Army rapidly directs a service contractor to establish [Dining Facilities At Camp] (DFACs) that serve three A rations per day and provide troops with 24-hour meal and beverage service."[191] As a result, "the MRE-related waste generated… diminishes over time", to be replaced by a significant amount of plastic packaging from the DFACs and consumable waste.[192] With 80% of a FP module's waste coming from the DFACs, the plastic and food waste from FOBs remains a critical roadblock to FOB sustainability.[193]

10.2 Characterization Studies

Several existing characterization studies evaluated the composition and quantity of solid waste streams at FOBs. The results of several of these studies are presented in Table 9, Characterization Studies.

Table 9. Characterization Studies[194]

	Army Field Feeding System (Fort Campbell, April 1995)	Force Provider Training Module (Fort Polk, June 2000)	AF Bare Base* (Derived from PSAB data)	ASG Eagle Base Camp (excluding wood)	ASG Eagle Base Camp (including wood)
Study Population	210	164	1182	3700	3700
Paper & Cardboard	45%	38%	53%	49%	12%
Plastic	8%	12%	26%	34%	8%
Food	14%	40%	2%	4%	1%
Misc	12%	7%	10%	8%	2%
Metal & Glass	21%	3%	6%	5%	1%
Wood	–	–	3%	–	76%
Per Capita (lbs/person/day)	3.2	4.1	13.2	3.0	12.6
Fuel Potential	79%	97%	94%	95%	99%

*** This data is estimated, and the methodology used was not specified.**

- Early planning factors (Vietnam – 2000) had ranged widely, from **1.64 lbs/d/soldier** for a 1998 Navy survey onboard an aircraft carrier to **85 lbs/d/soldier** from a Georgia Tech study based on 21 camps during Operation Joint Endeavor.[195] A 1999 study of the Prince Sultan Airbase calculated a planning factor of **28 lbs/d/soldier**.[196] According to a FP study, earlier studies found permanent, fixed installations generated **9 lbs/d/soldier** of solid waste, an overseas air base generated **21.2 lb/d/soldier**, and a field artillery unit generated **3.12 lbs/d/soldier**.[197]
- A study of FP modules determined that a 550 man FP module generated 2,500 lbs of solid waste per day, or **4.1 lbs/d/soldier**.[198] Another study determined that the 2,500 lbs of solid waste was equivalent to 410 kg of JP-8, or when converted to electricity at 25% efficiency, able to provide 51 KW of continuous power.[199]
- A 1,100 man HF bare-base general planning factor is **4 lb/d/soldier** (which coincidentally matches accounts of 80,000 lbs of daily waste at Victory Base)**,** but a study evaluating all planning factors found that a more appropriate planning factor was **10 lb/d/soldier**.[200]
- In 2003, USAREUR directed a study at Eagle Base to evaluate solid waste generation rates. That, along with similar other studies at Camp Bondsteel (Kosovo) and Camp Bulwark (Bulgaria), formed the basis for a 2004 characterization study that concluded a standard solid waste generation rate to be **15.8 lbs/d/soldier**. [201] In 2006, a second characterization study was performed for USAREUR at another camp in the Balkans. This data, published in a 2007 report, suggested that the solid waste stream was now **18.2 lbs/d/soldier**. [202] Although a comparison of the two studies shows a marked decrease in the percentage of the waste stream that is scrap wood, other components had unfortunately compensated for the difference."[203]

Table 10. 2003, 2006 Study[204]

	2006 Data (Camp B)		2003 Data (Camp A)	
Component	lb/person/yr	Percent	lb/person/yr	Percent
Plastic bottles	196	3.0	295	5.1
Other plastic	502	7.6	143	2.5
Aluminum	46	0.7	10	0.2
Light metal	202	3.0	11	0.2
Cardboard (and paper)	529	8.0	349	6.1
Other paper	974	14.7	179	3.1
Food and vegetation waste	609	9.2	418	7.3
Textiles	95	1.4	25	0.4
Glass	37	0.6	40	0.7
Rubber	4	0.1	4	0.1
Polystyrene	21	0.3	9	0.2
Scrap wood	1076	16.2	4151	72.1
Sewage sludge	688	10.4	70	1.2
Ashes	811	12.2		0.0
Miscellaneous	838	12.6	52	0.9
Total	6627	100.0	5756	100.0

10.3 Treatment and Disposal

FOBs generate a lot of solid waste.[205] The methods of managing that waste mirror the spectrum of wastewater treatment and power generation options between small, austere FOBs and larger, more established FOBs. In early, expeditionary phases of a contingency operation, "solid waste management has a very low priority. Field expedient measures of open dumping, burying, and limited burning of solid waste are standard practice of Army units on the move, and these practices continue in the initial base camp phases until the local threat level is low enough to allow units to address solid waste management as a general health and sanitation requirement."[206] With DODI 4715.5, *Management of Environmental Compliance at Overseas Installations*, exempting military contingency operations from strictly following several environmental requirements, expediency takes top priority in these situations, with waste burned with diesel fuel, wastewater dumped, and non-combustible waste stacked.[207] Once the FOB is more secure, waste management is then often performed by contractors, with the associated cost and safety ramifications.[208] Table 11, Solid Waste Management Example, provides one example of a camp's waste disposal procedures:

Table 11. Solid Waste Management Example[209]

Date	24 June 2002
Location	Camp Bondsteel
Point of contact	Ray Alderson
Service population	10,000 including contract local nationals.
Sources	Packaging, construction material.
Types and quantities	Plastics, glass, lumber is probably the biggest fraction.
On-site handling and storage	Dumpsters.
Collection method	Ten collection trucks.
Processing technique	Trash deposited in pole barn and searched by local nationals for explosives and hazardous wastes.
Disposal method	Incinerated in enclosed burn pit, transferred to cool down pad, and trucked to landfill for disposal.
Hazardous wastes	Stored in designated areas and transported to treatment facility.
Recycled materials	Lumber sent to fire demo pit for training. No recycling of cans and bottles. No paper recycling because of operational secrecy.
Lessons learned	Should have put garbage grinders in dining facilities so garbage would go to WWTP rather than solid waste facility.
Comments	All solid waste generated at Camp Monteith is incinerated at Bondsteel.

Landfills

Burying solid waste in landfills both on and off-site are typical methods of disposing of solid waste. Given the volume of solid waste, however, on-site landfills can quickly hamper the effectiveness and force protection capabilities of a FOB and create environmental, vector attraction, and quality-of-life problems.[210] With distances to off-site landfills in Iraq or Afghanistan often reaching 60 to 120 miles, transporting waste off the FOB can cost $4.6 million annually for a 7300 man FOB.[211]

Burn Pits, Incinerators, Burn Boxes, and Air Curtain Destructors

Burning can be used to reduce the volume and weight of paper, plastics, and other combustible items prior to burying or landfill disposal. Commercial incinerators can "efficiently reduce" Petroleum, Oil, and Lubricants (POL), other chemicals, DFAC waste, paper, and cardboard to a fraction of its original mass.[212]

Each method, however, also incurs costs. Sorting is required before burning to remove any hazardous items. Burn pits, boxes, and air curtain destructors require significant amounts of precious fuel and wood, and burning waste emits "toxic, acrid smoke, which has caused military personnel to complain about eye and lung irritation."[213] Incinerators can be unreliable and expensive to operate.[214] Regardless of the method, the residual from burning must still be buried or transported outside the FOB for disposal, incurring additional costs.

Hazardous Waste

Hazardous waste is collected in 55 gallon drums and taken to a satellite accumulation point.[215]

11 Going Forward

This section summarizes 1) key findings, 2) areas of potential future research, 3) parallel research, and 4) next steps.

11.1 Key Findings

Summary of key findings:

FOBs

- FOBs are critical to expeditionary warfighting and for waging asymmetric warfare
- Establishing and sustaining FOBs require significant logistical support
- FOBs can vary widely in sophistication, depending on size, support requirement, host-nation infrastructure, the nature of the operation (contingency, enduring), and anticipated duration (temporary, semi-permanent, permanent)

Planning

- Planning process characterized by decentralized management of details; extensive coordination required across a disparate set of parties
- No repository of best practices or consistent doctrine, standards
- No systematic, robust process for developing and implementing sustainable solutions
- Process characterized by tradeoffs, but mission success takes top priority

Supply

- The majority of materiel needed to build and sustain FOBs is brought into theater
- Redesign of supply strategy can contribute to more sustainable FOBs
- Transportation challenges differ based on geography (e.g., Iraq v. Afghanistan)
- Shipping containers can be redesigned for greater use at FOBs

Facilities

- Depending on the size and sophistication of the FOB, a FOB can have a wide variety of different types of buildings
- The least costly construction method utilizes existing infrastructure as much as possible
- Tents are simple to transport and use but consume significant fuel to heat/cool
- Cost of building material should factor into FOB design planning
- FOB sets, such as the Force Provider modules, have played a growing role in standardizing and simplifying field construction

Force Protection

- Successful force protection is vital to the survival of a FOB
- Using indigenous material and organic, creative solutions is key to a more sustainable FOB

Food

- Rations are delivered to the tactical edge. Preparation of certain types of rations requires energy/power for cooking and/or refrigeration.
- Rations are a source of solid and human waste

Water & Wastewater

- Water is critical to expeditionary campaign success
- Water consumption and wastewater generation planning factors vary depending on geography, doctrine, Service, and command; reflects the flexibility required in developing sustainable FOBs
- Water can be procured from host-nation infrastructure (reservoirs, irrigation systems, municipal

sources, and swimming pools), wells, natural surface sources, and bottled water
- Although officially the source of last resort according to U.S. military doctrine, bottled water is the principal source of drinking water at many FOBs throughout Afghanistan and Iraq. Not only is delivering bottled water expensive and dangerous, but the plastic bottles also become major sources of solid waste
- Wastewater treatment methods vary depending on size and sophistication of the FOB
- Burning waste, one disposal method at austere FOBs, can be hazardous to soldiers

Fuel, Energy, Power
- Fuel consumption has grown substantially since the Vietnam War, a consequence of technology and increasing complexity
- Fuel distribution faces IED attacks in Iraq and impassable terrain in Afghanistan
- The fully burdened cost of fuel can range to hundreds of dollars per gallon of delivered fuel
- FOB fuel usage estimates vary, depending on the size and primary mission of the FOB
- Support operations are a significant source of battlefield fuel demand
- Problems at FOBs: inefficient generators, excess generation, inefficient buildings
- Batteries represent a significant constraint on individual fighting capability

Solid Waste
- Accumulation of solid waste can become an environmental, health, and political liability
- Plastic water bottles, wood, and food packaging are three significant sources of waste. The wood from containers and pallets should be re-used at the FOB in some other capacity
- Solid waste generation rates differ depending on the characterization study in question
- There is a hierarchy of solid waste disposal methods, from burning waste to hiring contractors to haul waste from the FOB. Burning is prevalent in Afghanistan.

11.2 Areas of Potential Future Research

Summary of areas of potential future research and solution parameters:

Implications for Sustainability / Solution Parameters
- Solutions must be geography-neutral. Solutions can be inspired by need in one region, such as spray-foaming tents for insulation in Iraq or Afghanistan, but the ebb and flow of soldiers in Iraq and Afghanistan suggest that solutions should not be relevant for only one geography type. Anticipate the next contingency operation.
- Solutions must be modular, flexible, scaleable, and adaptable for the spectrum of FOB types, from austere, platoon-sized bases to full, division-sized main bases.
- Solutions must have commander buy-in from the beginning
- Solutions must take into account relevant concerns from all parties
- Solutions must account for operational and political reality
- Solutions must not obstruct – but enable – mission success
- Solutions must not jeopardize soldier health, safety, or morale
- Solutions must not hinder timely FOB development
- Solutions must adhere to current infrastructure and transportation requirements

Areas of Potential Future Research
- Develop strategy roadmap towards greater sustainability with the following steps: 1) fully utilize all materiel, 2) reduce demand, 3) minimize waste through reuse of materiel, and 4) reuse generated waste
- Develop decision-support tool that incorporates sustainable best practices
- Design materiel supply chain strategy to enhance sustainability

- Design shipping containers for use as FOB structures, force protection. Develop other creative uses for packaging material / pallets.
- Design and deploy real-time energy demand management / smart grid systems
- Design and build more energy efficient structures. Adopt efficiency best practices in selecting construction material used, lighting technology, window technology, layout. Consider integration of renewable energy generation (e.g., thin-film solar) with structures
- Identify state-of-art solutions to improve the energy efficiency of structures. Spray foam insulation is a good starting point, but it also prevents re-use
- Design construction material supply chain to enhance sustainability
- Improve current base "sets", like US Army Force Provider and USAF Harvest Falcon and Harvest Eagle
- Design and develop new force protection technologies that are lighter, stronger, made of local material, and easier to build
- Design supply chain to reduce need for transportation without risking soldier safety
- Design rations to reduce packaging waste (e.g., biodegradable packaging)
- Design more energy-efficient field kitchens
- Design process to convert waste (including grease) to fuel
- Identify ways to help promote sustainable behavior (e.g., less bottled water use, conservation)
- Develop more efficient, effective, and less energy-intensive water purifiers that produce tasteless water – both large scale and portable
- Develop strategy to expedite the certification of drinking water standards at FOBs
- Develop strategy to reduce bottled water consumption
- Design more sustainable wastewater treatment solutions
- Design process/technology to reuse wastewater
- Design more energy-efficient buildings that require less electricity
- Design energy supply/demand management software; run generators to meet supply
- Ensure compatibility between generators and appliances
- Develop training strategy/curriculum for interconnected power systems
- Design efficient, next generation power generators
- Design renewable energy generators specifically for FOBs
- Design methods to produce and use alternative fuels
- Reduce battery weight for individual soldiers
- Design supply strategy to streamline fuel distribution
- Design fuel recycling program
- Design more sustainable and safer disposal technologies/practices
- Develop recycling program; identify opportunities to re-use solid waste
- Design more efficient and reliable incinerators
- Develop safe treatment method for ash generated after burning

11.3 Parallel Research

Throughout the federal government, agencies and military Services have begun earnestly pursuing parallel paths towards sustainability. Some organizations have prioritized identifying immediate solutions while others have emphasized closing the gap with future research. Since no one solution will suffice, the following provides an abbreviated list of several other current research initiatives within the federal government to promote sustainable FOBs. Collaboration, communication, knowledge-sharing will be key to developing solutions in a timely and comprehensive manner.

Organization	Initiatives
Department of Defense	
Power Surety Task Force	Eskimo spray foam insulation; currently used in Iraq Transportable Hybrid Electric Power Systems (tested at Ft. Irwin) Net Zero Plus Joint Capability Technology Demonstration Monolithic Dome (tested at Ft. Irwin) Tactical Garbage to Energy Refinery (tested in Iraq) Hybrid Electric Power Station (to be tested in Kuwait)
Project Manager-Mobile Electric Power	Developing more fuel efficient generators (AMMPS) Development of central power generation system Hybrid Intelligent Power (smart grid)
Services	
Air Force	Built renewable energy tent city (Tyndall AFB)
Marine Corps	Developing Deployable Renewable Energy Alternative Module Created USMC Expeditionary Energy Office Developing Experimental FOB at Quantico to test sustainable products
Army (USACE)	Engineer Research and Development Center (ERDC)/ Center for the Advancement of Sustainability Innovations (CASI) workshops
Army Research, Development, and Engineering Command (RDECOM) / Army Research Laboratory (ARL)	Developing process to turn tires into energy and other products Demonstrate Waste-to-Fuel plants Sponsored Current and Future Base Camp Sustainability workshop (2007)
Army (Natick Soldier Systems Center)	Sponsored Expeditionary Base Camp workshop (2009)
Navy	Demonstration of fuel cell systems to provide portable power
Navy (Office of Naval Research)	Sustainability in logistics

Sources of other proposed research: Natick Expeditionary Basing Workshop, ARL Sustainable Base Workshop (http://www.ncsu.edu/kenan/ncsi/aro_base.html), USACE ERDC/CASI *Sustainable, Full Spectrum Contingency Operations Gap Assessment*, and *Defense Management: DOD Needs to Increase Attention on Fuel Demand Management at Forward-Deployed Locations*, GAO, February 2009.

11.4 Next Steps

Each of the previous sections deserves additional analysis to fully identify the gaps in current research that SERDP can help bridge. The Noblis team did not differentiate potential future research into short-term and long-term research needs, but there is a significant need for creative, out-of-the-box long-term research. The original white paper submitted by Noblis in August 2009 envisioned a four part process:

1. Define resource requirements and waste generation at FOBs
2. Assess current practices and operations
3. Identify gaps in the science, technology, and energy/waste management and propose RTD&E and best practices to bridge those gaps
4. Recommend approaches to accelerate the adoption and implementation of sustainable technologies and practices

This paper was designed to address the first two parts, with the second half – a detailed examination of future research opportunities for SERDP – to follow completion of this FOB characterization study. Subject to additional guidance from SERDP, Noblis proposes to complete the second half of the original proposed scope of work.

Appendices

Acronyms

AMC	Air Mobility Command
AMMPS	Advanced Medium Sized Mobile Power Sources
AOR	Area of Responsibility
ARL	Army Research Laboratory
BEAR	Basic Expeditionary Airfield Resources
CASI	Center for the Advancement of Sustainability Innovations
CDS	Container Delivery Systems
CENTCOM	U.S. Central Command
CHU	Containerized Housing Unit
CMU	Concrete Masonry Unit
DESC	Defense Energy Support Center
DFAC	Dining Facility
DLA	Defense Logistics Agency
DoD	Department of Defense
DPGDS	Deployable Power Generation and Distribution System
DRMS	Defense Reutilization & Marketing Service
DSCP	Defense Supply Center Philadelphia
DVD	Direct Vendor Delivery
EMD	Electro-motive Division
ERDC	Engineer Research and Development Center
FM	Field Manual
FOB	Forward Operating Base
FP	Force Provider (U.S. Army)
FSR	First Strike Ration
g/bw/d	Gallons of blackwater per day
g/gw/d	Gallons of graywater per day
g/w/d	Gallons of water per day
g/ww/d	Gallons of wastewater per day
GP	General Purpose tents
HE	Harvest Eagle (U.S. Air Force)
HF	Harvest Falcon (U.S. Air Force)
HN	Host nation
HVAC	Heating, Ventilation, and Air Conditioning
HZ	Hertz
IED	Improvised Explosive Device
ISO	International Organization for Standardization

ISU	Interval Sling-able Unit
KCLFF-E	Kitchen, Company-Level Field Feeding-Enhanced
KW	Kilowatt
LWP	Light Weight Purifier
MEB	Marine Expeditionary Battalion
MEP	Mobile Electric Power
MRE	Meals, Ready-to-Eat
MW	Megawatt
MWR	Morale, Welfare, Recreation
OEF	Operation Enduring Freedom
OIF	Operation Iraqi Freedom
POL	Petroleum, Oils, Lubricants
PRIME BEEF	Prime Base Engineer Emergency Force Squadron
PU	Prime Unit
PX	Post Exchange
RDECOM	U.S. Army Research, Development, and Engineering Command
ROWPU	Reverse Osmosis Water Purification Unit
SAA	Small Arms Ammunition
SEA Hut	Southeast Asia hut
Seabees	United States Navy Construction Battalions
SEE	Small Emplacement Excavator
SERDP	Strategic Environmental Research and Development Program
TEMPER	Tent Extendable Modular Personnel tents
TQG	Tactical Quiet Generator
TWPS	Tactical Water Purification System
UGR-A	Unitized Group Ration – A Option
UGR-B	Unitized Group Ration – B Option
UGR-E	Unitized Group Ration – Express
UGR-H&S	Unitized Group Ration – Heat & Serve
USACE	U.S. Army Corps of Engineers
USAF	U.S. Air Force
USAREUR	U.S. Army, Europe
USTRANSCOM	U.S. Transportation Command
V	Volt

Appendix A Summary FOB Characterization

Source: Multiple sources

	FOB tactical base (50)	**FOB tactical base** (500)	**FOB main operations base** (1,500)	**Enduring main operations base** (10,000)
General				
Type of FOB[216]	Small, platoon-sized FOB designed for tactical operations and co-location within population centers. Provides secure location with only enough logistics capacity to support the camp.	Company or battalion-sized FOB designed for larger tactical operations or missions with a longer duration. Provides secure location with only enough logistics capacity to support the camp.	Regiment or brigade-sized FOB functioning as a main operations base. Has sufficiently robust infrastructure to support a wide variety of missions and can include service member support facilities. Military training, civil affairs missions, and even the capacity to support civilian political functions and NGO activities may be included.	Division-sized FOB functioning as an enduring, semi-permanent main operations base. Has relatively sophisticated infrastructure capable of supporting sustained operations.
Size (# of troops supported)	50	500	1,500	10,000
Footprint[217]	2 acres	16 acres	51 acres	350 acres
Location	**Austere** - Limited host-nation infrastructure - Example: Afghanistan	**Austere** - Limited host-nation infrastructure - Example: Afghanistan	**Sophisticated** - Some host-nation infrastructure - Example: Iraq	**Sophisticated** - Some host-nation infrastructure - Example: Iraq
Mission duration	**Organic** Less than 90 days	**Initial** Less than 6 months	**Temporary** Less than 2 years	**Enduring (Semi-Permanent)** Less than 10 years

	FOB tactical base (50)	**FOB tactical base** (500)	**FOB main operations base** (1,500)	**Enduring main operations base** (10,000)
General				
Construction standards (Source: USACE)[218]	Organic construction is typical of what would be found in a tactical assembly area. Organic standard construction is set up on an expedient basis with no external engineer support, using unit organic equipment and systems or HN resources. Intended for use up to 90 days, it may be used for up to six months.	Characterized by minimum facilities that require minimal engineer effort and simplified material transport and availability, initial standard construction is intended for immediate use by units upon arrival in theater for up to six months. The primary difference between organic and initial standards is the application of engineer effort to improve living conditions above what the unit is able to accomplish on its own.	Characterized by somewhat minimal facilities, temporary standard construction is intended to increase efficiency of operations for use extending to 24 months, but may fulfill enduring phase standards and extend to 5 years. It provides for sustained operations and may replace initial standard in some cases where mission requirements dictate and require replacement during the course of extended operations. It requires extensive engineer support and may involve new construction, rather than limiting operations to tents and existing facilities.	The standard construction standards at these FOBs reflect a life expectancy of more than two, but less than ten, years. The types of structures used will depend on duration. This standard may be used initially after carefully considering the political situation, cost, quality of life, and other criteria.
Site work[219]	None to minimal site work; maximized use of existing facilities	Clearing and grading for facilities including drainage, revetments of POL, ammo storage, and airfield parking.	Engineered site prep, including paved surfaces, building foundations, and concrete floor slabs	Engineered site preparation
Construction[220]	18,264 man-hours*	120,502 man-hours	240,070 man-hours	800,233 man-hours

* Data extrapolated for 50-man FOB

	FOB tactical base (50)	**FOB tactical base** (500)	**FOB main operations base** (1,500)	**Enduring main operations base** (10,000)
Facilities				
Available facilities[221]	Housing, basic latrines and septic systems, minimal offices, minimal dining facilities, gravel roads, minimal medical facilities, post-exchange, fitness center, minimal MWR facilities	Housing, basic latrines and septic systems, offices, dining facilities may be operated by contractors, roads, medical facilities, post-exchange, fitness centers, MWR facilities, finance/postal/legal maybe offered, warehouses, laundry, maintenance	Housing, latrines and septic systems, laundry, offices, dining facilities operated by contractors, roads, warehouses, finance and postal services, aviation, medical facilities, post-exchange, athletic fields, MWR facilities	Housing, latrines and septic systems, laundry, offices, dining facilities operated by contractors, roads, warehouses, finance and postal services, aviation, medical facilities, post-exchange, athletic fields, MWR facilities
Housing standard[222]	- Pre-existing structures - Tents (Tier I - no floor, non-permanent)	- Pre-existing structures - Tents (Tier II, III - wooden floors, lights, pole-supported, electrical outlets) - Could include prefabricated housing (trailers) and limited new construction	- Tents (Tier III - wood floor, 2/3 wood walls) - Wood frame structures, SEA Huts - Modular buildings - Containers	-Wood frame structures, SEA Huts - Modular buildings - Containers - Pre-fabricated buildings - Masonry, steel buildings
Housing[223],[†]	3,980 square feet	39,800 square feet	119,400 square feet	796,000 square feet
Dining facility[224]	- Tents - Assault kitchens (KCLFF-E)	- Tier I-III tents - Mobile kitchen trailer - Containerized kitchen	- Tier III tents - SEA Huts - Masonry, pre-fabricated buildings	- SEA Huts - Masonry, pre-fabricated buildings
MWR[225]	Limited MWR facilities	Limited MWR facilities, could include internet cafés, phone service, and PX trailers (depending on camp size and location)	Depending on the length of time personnel may occupy the base, may include up to theater facilities, PX, internet cafés, long distance phone service, ball fields, gyms, and organized recreation events	Depending on the length of time personnel may occupy the base, may include up to theater facilities, PX, internet cafés, long distance phone service, ball fields, gyms, and organized recreation events

[†] 20/80 officer to enlisted ratio, 110 sq ft / officer, 72 sq ft / enlisted

	FOB tactical base (50)	FOB tactical base (500)	FOB main operations base (1,500)	Enduring main operations base (10,000)
Force Protection				
Standards	Concertina fences, sandbags, limited guard towers, limited use of concrete masonry	Triple standard concertina fence, sandbags, berms, serpentine for entry point control	Triple standard concertina fence, berms, guard towers, greater use of HESCOs, concrete barriers	Extensive force protection measures
Food				
Rations	-MREs - UGR-Es	-MREs - UGR-H&S	-UGR-H&S - A-Rations (UGR-A)	-UGR-H&S - A-Rations (UGR-A)
Water				
Quantity‡	1,750 gallons / day	17,500 gallons / day	52,500 gallons / day	350,000 gallons / day
Source[226]	- Wells - Bottled water	- Wells - Bottled water - Surface water (using ROWPUs)	- Wells - Bottled water - Surface water (using ROWPUs) - Treatment plants - Existing infrastructure	- Wells - Bottled water - Treatment plants - Existing infrastructure
Wastewater				
Quantity (total)§	1,750 gallons / day	17,500 gallons / day	52,500 gallons / day	350,000 gallons / day
Graywater	1,487 gallons / day	14,875 gallons / day	44,625 gallons / day	297,500 gallons / day
Blackwater**	263 gallons / day	2,625 gallons / day	7,875 gallons / day	52,500 gallons / day
Treatment[227]	Rudimentary infrastructure/practices: - Unit field sanitation kits and pit latrines - Burn out latrines - Direct disposal (mostly of graywater) - Limited use of leach fields, lagoons	- Pit latrines - Burn out latrines - Chemical latrines / contractor disposal - Possibly lagoons, leach fields - Limited possibility for wastewater treatment plants	- Ranges from chemical latrines and contractor disposal to lagoons, central sewer system, and wastewater treatment plants	- Most likely wastewater treatment plant

‡ Assuming 35 gallons / person / day

§ Assuming 35 gallons / person / day

** Assuming blackwater comprises 15% of total wastewater volume

	FOB tactical base (50)	**FOB tactical base** (500)	**FOB main operations base** (1,500)	**Enduring main operations base** (10,000)
Fuel & Power				
Fuel usage††	250 gallons / day	2,500 gallons / day	7,500 gallons / day	50,000 gallons / day
Power demand (peak)‡‡	50 KW or less	500 KW	1.5 MW	10 MW
Source of power	Limited need for electricity, use of unit tactical generators whenever needed; batteries	Distributed generation. Tactical military generators, commercial generators, up to Army Prime Power	Larger generators, both commercial and military. Consolidation of generators to form centralized power plants. Limited use of host-nation electric grid	Centralized commercial power plants and use of host-nation electric grid
Solid Waste				
Quantity§§	500 pounds / day	5,000 pounds / day	15,000 pounds / day	100,000 pounds / day
Disposal	- Burn pits	- Burn pits - Incinerators - Some landfill use	- Incinerators - Landfills - Contractor removal - Limited recycling	- Incinerators - Landfills - Contractor removal - Recycling /composting - Host nation treatment

†† Assuming 5 gallons / person / day

‡‡ Assuming 1 kw of peak demand / person

§§ Assuming 10 pounds / person / day

Appendix B U.S. Army Field Manual 3-34 Standards

Source: US Army FM 3-34

Table E-16. Example of initial, temporary, and semipermanent facility standards

Facility	*Initial (Less Than 6 Months)*	*Temporary (6 Months to Less Than 24 Months)*	*Semipermanent (2 Years to Less Than 10 Years)*
American forces network-manned operations	None	Container, SEAhut	Container; SEAhut; metal, prefabricated building
American forces network-unmanned operations	None	Container, SEAhut	Container; SEAhut; metal, prefabricated building
Alteration/pressing shop	None	Tier III tents, SEAhuts, containers	SEAhuts, containers: 2 to 10 years Masonry and prefabricated buildings: 10 or more years
ASG, area support team	None	Tier III tents, SEAhuts, containers	SEAhuts and containers: 2 to 10 years Masonry and prefabricated buildings: 10 or more years
ASP	Containers	Containers to bunkers	Bunkers
Athletic fields	None	Grassed fields	Grassed fields with lights
Aviation fuel	HEMTT tanker	Bladder	Metal tanks, steel lines
Aviation maintenance	Organic tentage, force provider[1]	Aviation clamshell tent with sand-filled plywood, asphalt, or concrete floor	Aviation clamshell tent with sand-filled plywood, asphalt, or concrete floor
Barber shop, beauty shop	None	Tier III tent, SEAhuts, containers	SEAhuts, containers: 2 to 10 years Masonry and prefabricated buildings: 10 or more years
Basic load ammunition holding area, captured ammunition holding area	Military vans (container) with earth berms	Earth-covered, standard, steel-reinforced bunkers on concrete pads with berms	Earth-covered, standard, steel-reinforced bunkers on concrete pads with berms
Chapel	Organic tentage with wooden floors, Tier I tents, "Chapel-in-a-Box", force provider[1]	SEAhut, containers	Davidson-like, wood-frame building; SEAhuts; containers: 2 to 10 years Masonry and prefabricated buildings: 10

Table E-16. Example of initial, temporary, and semipermanent facility standards

Facility	*Initial (Less Than 6 Months)*	*Temporary (6 Months to Less Than 24 Months)*	*Semipermanent (2 Years to Less Than 10 Years)*
			or more years
Cold storage	Portable refrigeration with freezer units for medical, food, and maintenance storage	Refrigeration installed in temporary structures	Refrigeration installed in semipermanent structures: may be preengineered buildings
Communications compound, national service center	Organic tentage with wooden floors, Tier I tents, force provider[2]	Tier III tents, SEAhuts, containers	SEAhuts and containers: 2 to 10 years Masonry and prefabricated buildings: 10 or more years
Community activity center	None	SEAhuts	SEAhuts: 2 to 10 years Masonry and prefabricated buildings: 10 or more years
Dining facility	Mobile kitchen trailer, organic tentage with wooden floors, Tier I tents, personnel protection[1]	Tier III tents, SEAhuts, fest tents	SEAhuts: 2 to 10 years Masonry and prefabricated building: 10 or more years
Defense Reutilization and Marketing Office	None	Metal, prefabricated building with concrete or asphalt floor and gravel holding area	Metal, prefabricated building with concrete or asphalt floor with gravel holding area
DS maintenance	Organic tentage or force provider[2]	Metal, two-story prefabricated building on concrete base with concrete aprons	Metal, two-story prefabricated building on concrete base with concrete aprons
Direct exchange, central issue facility	None	Tier III tents, SEAhuts, containers, metal prefabricated building	SEAhuts and containers: 2 to 10 years Masonry and prefabricated buildings: 10 or more years
Education center	None	Tier III tents, SEAhuts, containers, metal prefabricated building	SEAhuts, containers: 2 to 10 years Masonry and prefabricated buildings: 10 or more years

Table E-16. Example of initial, temporary, and semipermanent facility standards

Facility	*Initial (Less Than 6 Months)*	*Temporary (6 Months to Less Than 24 Months)*	*Semipermanent (2 Years to Less Than 10 Years)*
Electrical	Tactical generators with high- and low-voltage distribution, organic equipment, force provider[1]	Commercial power with nontactical power and high- or low-voltage distribution backup	Commercial power with nontactical power and high- or low-voltage distribution backup
Field house, multipurpose facility	None	Metal, prefabricated building	Metal prefabricated building
Finance and personnel support operations	None	Tier III tents, SEAhuts, containers	SEAhuts and containers: 2 to 10 years Masonry and prefabricated buildings: 10 or more years
Fire protection	Organic equipment, portable fire extinguishers	See paragraph 11-63.	See paragraph 11-63.
Fitness center	None	SEAhuts; metal, prefabricated building	SEAhuts: 2 to 10 years Masonry and prefabricated buildings: 10 or more years
Ground fuel	Organic equipment, bags, force provider with secondary containment	Bladders with secondary containment	Metal tanks with steel lines with secondary containment
HAZMAT warehouse	Storage container	SEAhuts or metal, prefabricated building with secondary containment	SEAhuts and metal, prefabricated buildings and secondary containment: 2 to 10 years Masonry and metal, prefabricated buildings with secondary containment: 10 or more years
Hazardous waste	Storage container, removal from theater	Covered, built-on elevated pad with secondary containment (civilian contract removal)	Covered, built-on elevated pad with secondary containment (civilian contract removal)
Helipad	Tactical surfacing, including matting	Concrete with aprons	Concrete with aprons

Table E-16. Example of initial, temporary, and semipermanent facility standards

Facility	*Initial (Less Than 6 Months)*	*Temporary (6 Months to Less Than 24 Months)*	*Semipermanent (2 Years to Less Than 10 Years)*
Housing	Organic tentage with wooden floors, Tier I tents, force provider[1]	Tier III tents, SEAhuts, containers	SEAhuts and containers: 2 to 10 years Masonry and prefabricated buildings: 10 or more years
Kennel	Organic tentage, Tier I tents (DA Pamphlet 190-12)	SEAhuts, container-adapted to DA Pamphlet 190-12 criteria	SEAhuts and containers adapted to DA Pamphlet 190-12 criteria
Latrines and septic systems	Organic equipment, evaporative ponds, pit burnout latrines, lagoons for hospitals, force provider[1]	Waterborne from ablution units or SEAhuts to austere treatment facility	Waterborne to wastewater treatment plant from SEAhuts and ablution units: 2 to 10 years Masonry and prefabricated buildings: 10 or more years
Laundry collection and distribution point	Organic tentage with wooden floors, Tier I tents, force provider[1]	Tier III tents, SEAhuts, containers	SEAhuts and containers: 2 to 10 years Masonry and prefabricated buildings: 10 or more years
Medical (See paragraph 11-24 for further guidance.)	Organic tentage with wooden floors, medical tents, Tier I tents	SEAhuts; medical metal, prefabricated buildings; refrigerated containers	SEAhuts; medical metal, prefabricated buildings: 2 to 10 years Masonry and medical, metal prefabricated buildings: 10 or more years
Medical waste	Field incinerator	Incinerator, civilian contract	Incinerator, civilian contract
Military police station	Organic tentage with wooden floors, Tier I tents, force provider[1]	Tier III tents, SEAhuts, containers	SEAhuts and containers: 2 to 10 years Masonry and prefabricated buildings: 10 or more years
Morgue	Refrigerated container	SEAhut, container with Gortex for private fencing, refrigerated container	SEAhuts and containers: 2 to 10 years Masonry and prefabricated buildings: 10 or more years
Multipurpose theater	None	Metal, prefabricated building	Metal, prefabricated buildings

Table E-16. Example of initial, temporary, and semipermanent facility standards

Facility	*Initial (Less Than 6 Months)*	*Temporary (6 Months to Less Than 24 Months)*	*Semipermanent (2 Years to Less Than 10 Years)*
MWR warehouse, maintenance facility	None	Metal, prefabricated building	Metal, prefabricated buildings
Nonpotable water	Local source	Local source	Local source
Office	Organic tentage with wooden floors, Tier I tents, FP[1]	Tier III tents, SEAhuts, containers	SEAhuts and containers: 2 to 10 years Masonry or prefabricated buildings: 10 or more years
Parking lots	Gravel	Gravel with concrete turning pads for tracked vehicles	Gravel with concrete turning pads for tracked vehicles
Perimeter fence	Triple standard	USACE Standard FE6	USACE Standard FE6
Perimeter lights	Generator sets	Fixed lighting	Fixed lighting
Postal	None	Metal, prefabricated building	Metal, prefabricated building
PX	AAFES trailer	Davidson-like, wood-frame building; metal prefabricated building	Metal, prefabricated building
Post warehouse	AAFES trailer	Davidson-like, wood-frame building; container; metal prefabricated building	Metal, prefabricated building
Potable water	Bottled water or water points, wells, other potable-water production and pressurized water distribution systems, reverse osmosis water purification unit, force provider	Wells, treatment plants	Wells, treatment plants
Road	Gravel	Gravel	Primary roads: asphalt with concrete turning pads Secondary and perimeter patrol roads: gravel
Runway and taxiway	Tactical surfacing, including aggregate and stabilized earth	Paved	Paved

Table E-16. Example of initial, temporary, and semipermanent facility standards

Facility	*Initial (Less Than 6 Months)*	*Temporary (6 Months to Less Than 24 Months)*	*Semipermanent (2 Years to Less Than 10 Years)*
Shower	Organic equipment, personnel protection[1]	Ablution units or SEAhuts	SEAhuts and AB units: 2 to 10 years Masonry or prefabricated buildings: 10 or more years
Solid waste	Field incinerator	Incinerator, civilian contract and recycling when possible	Incinerator, civilian contract, recycling program, composting
Squadron operations building	Organic tentage with wooden floors, Tier I tents, force provider[1]	SEAhuts, metal prefabricated building	SEAhuts and metal prefabricated buildings: 2 to 10 years Masonry and metal prefabricated buildings: 10 or more years
Supply support activity warehouse	Organic tentage with wooden floors, Tier I tents, force provider[1]	Metal, prefabricated building	Metal, prefabricated building
Training facilities	None	See paragraph 11-64.	See paragraph 11-64.
Vehicle maintenance	Organic tentage, force provider[1]	Metal, two-story, prefabricated building on concrete base with concrete aprons	Metal, two-story, prefabricated building on concrete base with concrete aprons
Washrack	Gravel lot	Gravel lot with oil-water separator and gray-water discharge	Elevated, flat, and container rack with oil-water separator and gray-water discharge

[1]Force provider: Each force provider module supports 550 personnel, plus 50 operators with climate-controlled billeting (with planning factors of 15 Soldiers per tent); food service (1,800 A-rations meals per day); laundry service (200 pounds per hour); showers and latrines (one 10-minute shower per day); MWR facilities and equipment; power (60-kilowatt tactical quiet generators [1.1. megawatts continuous]); prime power connection kit; water storage and distribution (80,000 gallons for every 3 days); fuel storage and distribution (20,000 gallons for every 3 days); waste-water collection (30,000 gallons per day); and system support packages (30 days spare and repair parts).

Appendix C U.S. Army Corps of Engineers Standards

Source: US Army Corps of Engineers, Base Camp Development in the Theater of Operations, January 19, 2009

Table C-1. Contingency construction standards in theater

Contingency Construction Standards in Theater			
Organic Standards • Support on expedient basis with no external engineer support. • Uses unit organic equipment and systems and/or HN resources. • Mission duration typically 1-90 days. • Provides for initial force presence and maneuver activities until force flow supports arrival of engineer resources.			
Initial Standards • Characterized by austere facilities requiring minimal engineer effort. • Intended for immediate operational use by units upon arrival for a limited time ranging up to 6 months. • May require replacement by more substantial or durable facilities during the course of operations.			
Temporary Standards • Characterized by austere facilities requiring additional engineer effort above that required for initial standard facilities. • Intended to increase efficiency of operations for use up to 24 months. • Provides for sustained operations. • Replaces initial standard in some cases where mission requirements dictate. The temporary standard may be used initially if so directed by the CCDR.			
Types of Construction	**Organic**	**Initial**	**Temporary**
Site Work	Minimal to no site work; maximized use of existing facilities	Clearing and grading for facilities including drainage; revetments of POL, ammo storage, and airfield parking; aggregate for heavily used hardstands; and soil stabilization	Engineered site preparation, including paved surfaces for vehicle traffic areas and aircraft parking, building foundations, and concrete floor slabs
Troop Housing	Unit tents	Tents (may have wood frames and flooring)	Wood frame structures, relocateable structures and modular building systems
Electricity	Unit tactical generators	Tactical generators: high and low voltage distribution	Nontactical or commercial power and high or low voltage

Table C-1. Contingency construction standards in theater

Contingency Construction Standards in Theater			
Water	Water points and bladders	Water points, wells, and/or potable water production and pressurized water distribution systems	Limited pressurized water distribution systems that support hospitals, dining halls, fire fighting, and other major use
Cold Storage	Contracted or unit purchased	Portable refrigeration with freezer units for medical, food, and maintenance storage	Refrigeration installed in temporary structures
Sanitation	Unit field sanitation kits and pit latrines	Organic equipment, evaporative ponds, pits or burnout latrines, lagoons for hospitals, and sewage lift stations	Waterborne to austere treatment facilities—priorities are hospitals, dining halls, bathhouses, decontamination sites, and other high volume users
Airfield Pavements*		Tactical surfacing, including matting, aggregate, soil stabilization, and concrete pads	Conventional pavements
Fuel Storage	Bladders	Bladders	Bladders and steel tanks
*The type of airfield surfacing to be used will be based on soil conditions and the expected weight and number of aircraft involved in operations.			

Appendix D Red Book Standards

Source: USAREUR, Base Camp Facilities Standards for Contingency Operations (Red Book)

ANNEX 2
AUTHORIZED FACILITIES LIST

FACILITY	MAIN BASE CAMP	FORWARD OPERATING BASE	OUTPOST
Roads	YES	YES (only gravel)	YES (only gravel)
DFAC	YES	YES	NO
Housing	YES	YES	YES (Tents Only)
Latrines and Septic Systems	YES	YES	YES (portable)
Shower	YES	YES	YES
Office	YES	YES	YES (Tents Only)
SSA/Warehouse	YES	NO	NO
DX/CIF	YES	NO	NO
Finance and Personnel Support Operations	YES	Operationally Defined	NO
Postal Facility	YES	NO	NO
Laundry Collection/Distribution Point	YES	YES	NO
Helipad	YES	YES	Operationally Defined
Runway and Taxiway	YES	NO	NO
Aviation Fuel	YES	Operationally Defined	NO
Squadron Operations Building	YES	NO	NO
Aviation Maintenance	YES	Operationally Defined	NO
Communications Compound/NSC	YES	Operationally Defined	NO
Medical	YES	YES (Aid Stations)	MEDICS

FACILITY	MAIN BASE CAMP	FORWARD OPERATING BASE	OUTPOST
Vehicle Maintenance	YES	YES	NO
Ground Fuel	YES	YES	NO
Hazardous Waste Collection Point	YES	YES	NO
Hazardous Materials Warehouse	YES	NO	NO
Parking Lots	YES	YES	Operationally Defined
DS Maintenance	YES	NO	NO
Kennel	YES	Operationally Defined	Operationally Defined
Morgue	YES	NO	NO
DRMO	YES	NO	NO
ASP	YES	NO	NO
BLAHA/CAHA	YES	NO	NO
Wash Rack	YES	NO	NO
Fire Protection	YES	YES (but different level)	YES (but different level)
Training Facilities	YES	NO	NO
MP Station	YES	Operationally Defined	NO
ASG	YES	NO	NO
Cold Storage	YES	Operationally Defined	NO
Chapel	YES	NO	NO
Education Center	YES	YES (combined with Community Activities)	NO
Barber/Beauty Shop	YES	YES	NO

FACILITY	MAIN BASE CAMP	FORWARD OPERATING BASE	OUTPOST
Alteration/Pressing Shop	YES	NO	NO
PX	YES	YES	AAFES Trailer
PX Warehouse	YES	NO	NO
Fitness Center	YES	YES	YES (Tents Only)
Field House/Multipurpose Facility	YES	YES	NO
Athletic Fields	YES	YES (limited)	NO
Community Activity Center	YES	YES (combined with Education Center)	YES (Tent Only for Recreation/Break Room)
Multi-Purpose Theater	YES	NO	NO
MWR Warehouse/Maintenance Facility	YES	NO	NO
AFN Manned Operations	YES	NO	NO
AFN Unmanned Operations	YES	YES	NO

Appendix E USACE General Land Use Planning Factors

Source: US Army Corps of Engineers, Base Camp Development in the Theater of Operations, January 19, 2009

Table E-2. General Base Camp Land Use Planning Factors

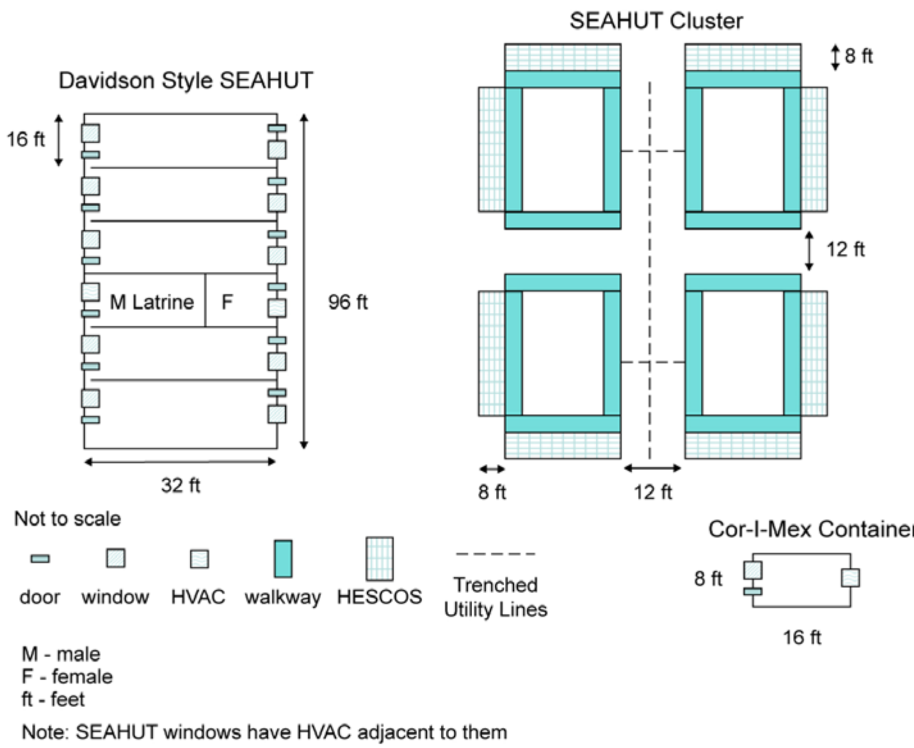
Land Use	Area (in acres)	Suggested Range (in acres)	Facilities Included	Remarks
Industrial	155	150-160	Wastewater treatment, electrical generation, incinerator, vehicle maintenance	
Community/ Administrative	99	90-110	Medical, fire and rescue, postal, dining, headquarters, briefing/chapel, parade field	
Troop Housing	230	225-250	Housing, showers, latrines, bunkers	Includes expansion capability (surge areas).
Supply/Storage	453	430-460	Military vehicle parking, wash racks, ammunition storage, open storage	
Morale/Welfare/ Recreation	65	50-75		
Heliport Facilities	129	110-130	Heliport aprons, tie-down area, maintenance hangar, operations, control tower, available fuel storage and truck parking, radar site	This is for a heliport of 12 helipads. If only one helipad is needed, less land would be required.
Open Space/Buffer	703	650-850	ECPs, guard towers, AT/FP buffers	Includes 350 acres of clear space outside the security fence.
Contractor Area	108	75-150		

Appendix F Life Support Area Planning Factors

Source: US Army Corps of Engineers, Base Camp Development in the Theater of Operations, January 19, 2009; US Army FM 3-34 (image revised)

Table 11-2. Recommended square footage for personnel accommodations

Category	*Net Square Feet*	*Number Per SEAhut*	*Number Per Container (8 x 20)*
E1 through E5	80	6	2
E6 through E7, WO-1/2, O1/2	130	4	2
E8, CW-3/4, O3/4	160	3	2
E9, CW5, O5/6	256	2	1
O7+	512	1	1



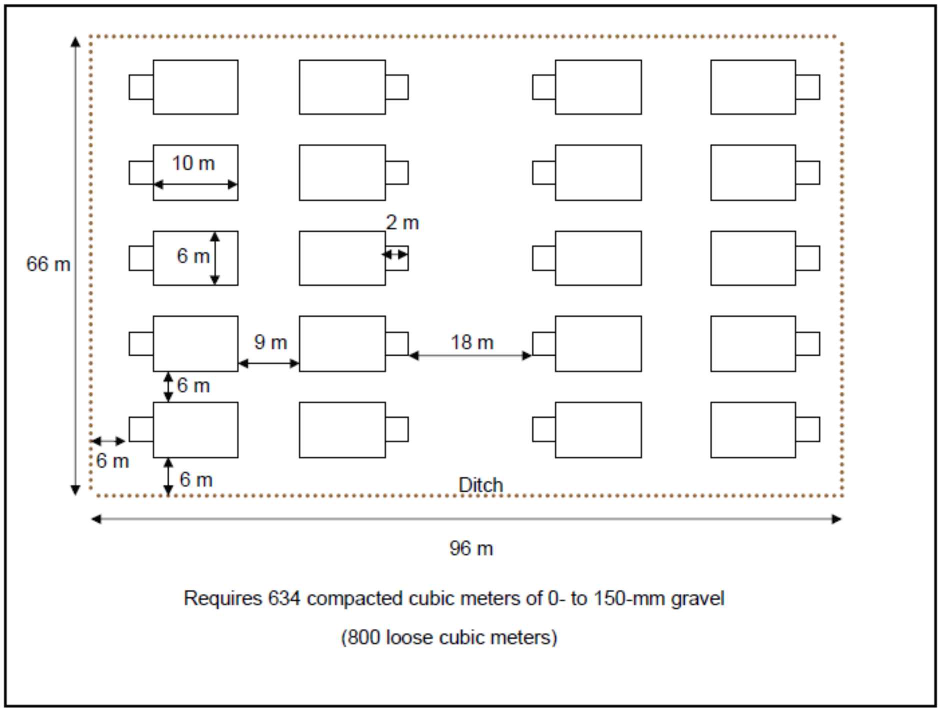


Figure 11-7. Standard life support area

Appendix G Construction Estimates - USACE

Source: US Army Corps of Engineers, Base Camp Development in the Theater of Operations, January 19, 2009

E-5. Tables E-3 and E-4 describe the general construction effort requirements necessary for typical site preparation and basic facilities for a 500-man base camp.

Table E-3. Construction effort, site preparation requirements

Facility Description	Size (sq yd)	Basis	Qty	Man-Hours			
				Hor	Ver	Gen	Total
Road, Class A, 1-inch multisurface, 1-mile	—	as required	0.2	58	NA	10	68
Hardstand	1,000	as required	4.0	168	NA	80	248
Road, Class A, graded and drained		as required	0.2	235	NA	84	319
Hardstand	1,000	as required	4.0	288	NA	104	392
Site preparation, 1-acre	—	as required	5.0	440	NA	160	600
TOTAL				*3,506*	*33,175*	*10,232*	*46,913*

Table E-4. Construction effort, facilities requirements (temporary to semipermanent standard, temperate climate, or wood frame)

Facility Description	Size	Basis	Quanity	Man-Hours			
				Hor	Ver	Gen	Total
Shop, motor repair	48 x 48 x 14 ft	1 per 100 vehicles	1	55	1,185	287	1,527
Storehouse	20 x 50 x 8 ft	2 sq ft per man	1	32	461	136	629
Dispensary	20 x 60 x 8 ft	1 per 500 men	1	33	1,290	115	1,438
Headquarters and unit supply	20 x 40 x 8 ft	1 per 200 men	3	84	1,293	240	1,617
Barracks, 500-man	20 x 100 x 8 ft	40 sq ft per man	10	450	7,510	1,860	9,820
Kitchen	—	1 per 250 men	2	154	10,352	3,788	14,294
Bathhouse and latrine	20 x 30 x 8 ft	1 shower per 10 men	1	24	941	61	1,026
Bathhouse and latrine	20 x 80 x 8 ft	1 shower per 24 men	1	39	1,754	150	1,943
Quarters (officer)	20 x 100 x 8 ft	80 sq ft per officer	1	45	869	186	1,100
Guard house	20 x 60 x 8 ft	1 to 250 men	1	33	626	115	774
Day room	40 x 60 x 8 ft	5 sq ft per man	1	43	868	178	1,089
Electric distribution	500-man	light and power	1	56	460	192	708
Boiler plant	—	1/2 mess	1	208	4,112	1,200	5,520
Drainage	500-man	17.5 GPD	1	205	384	490	1,079
Water supply well	—	as required	1	396	45	230	671
Water tank	200 gallons	as required	1		105	4	109
Water distribution	500-man	25 GPD per man	1	352	812	416	1,580
Sump fire	10,000 gallons	effective radius 500 feet	1	16	108	16	240

Appendix H Rations

Source: Customer Ordering Handbook & Update, Defense Supply Center Philadelphia

Ration/Item	Srvngs per U/I	U/I per Pallet	Srvngs per Plt	Case Cube	Case l/w/h (in.)	Case Wt(lb)	Cs per U/I	U/I Cube	U/I Wt(lb)	Cs per Pallet	Unit Load l/w/h (in.)	Unit Load Cube	Unit Load Avg. Wt(lb)
MRE	12	48	576	1.02	17x9.6x10.8	22	1	1.02	22	48	44.5x51.75x42.2	56.1	1098
MCW/LRP	12	48	576	1.02	17x9.6x10.8	15	1	1.02	15	48	44.5x51.75x42.2	57.1	758
HDR	10	48	480	1.02	17x9.6x10.8	25	1	1.02	25	48	44.5x51.75x42.2	58.1	1237
Religious Meal	12	30	360	1.4	19.6x13.75x9	18	1	1.4	18	30	41.25x39.25x46.25	43.3	540
UGR-H&S B1	50	8	400				3	5.25	134	24	48Lx40Wx41.5H	47.8	1071
UGR-H&S B2	50	8	400				3	5.25	105	24	48Lx40Wx41.5H	47.8	839
UGR-H&S B3	50	8	400				3	5.25	122	24	48Lx40Wx41.5H	47.8	976
UGR-H&S B4	50	8	400				3	5.25	109	24	48Lx40Wx41.5H	47.8	875
UGR-H&S B5	50	8	400				3	5.25	117	24	48Lx40Wx41.5H	47.8	936
UGR-H&S B6	50	8	400				3	5.25	110	24	48Lx40Wx41.5H	47.8	883
UGR-H&S B7	50	8	400				3	5.25	119	24	48Lx40Wx41.5H	47.8	952
Avg Brk	**50**		**400**						**116**				**933**
UGR-H&S D1	50	8	400				3	5.25	124	24	48Lx40Wx41.5H	47.8	995
UGR-H&S D2	50	8	400				3	5.25	113	24	48Lx40Wx41.5H	47.8	908
UGR-H&S D3	50	8	400				3	5.25	154	24	48Lx40Wx41.5H	47.8	1232
UGR-H&S D4	50	8	400				3	5.25	120	24	48Lx40Wx41.5H	47.8	960
UGR-H&S D5	50	8	400				3	5.25	133	24	48Lx40Wx41.5H	47.8	1064
UGR-H&S D6	50	8	400				3	5.25	136	24	48Lx40Wx41.5H	47.8	1088
UGR-H&S D7	50	8	400				3	5.25	131	24	48Lx40Wx41.5H	47.8	1048
UGR-H&S D8	50	8	400				3	5.25	144	24	48Lx40Wx41.5H	47.8	1153
UGR-H&S D9	50	8	400				3	5.25	126	24	48Lx40Wx41.5H	47.8	1008
UGR-H&S D10	50	8	400				3	5.25	138	24	48Lx40Wx41.5H	47.8	1105
UGR-H&S D11	50	8	400				3	5.25	141	24	48Lx40Wx41.5H	47.8	1127
UGR-H&S D12	50	8	400				3	5.25	132	24	48Lx40Wx41.5H	47.8	1054
UGR-H&S D13	50	8	400				3	5.25	131	24	48Lx40Wx41.5H	47.8	1048
UGR-H&S D14	50	8	400				3	5.25	132	24	48Lx40Wx41.5H	47.8	1056
Avg Din	**50**		**400**						**133**				**1068**
UGR-E (AVG)	18	18	324				1	1.9	43	18			
UHT Milk	27	120	3240	0.33	15.75x8x4.4		1	0.33		120	48x40x43	42.8	1970
Brk Cereal	72	50	3600	1.00	16x9x12		1	1.00		50	48x40x65	50.0	460

Appendix I USAREUR Contingency Menu

Source: Capt Ed Rackauskas, *Subsistence*, DSCP

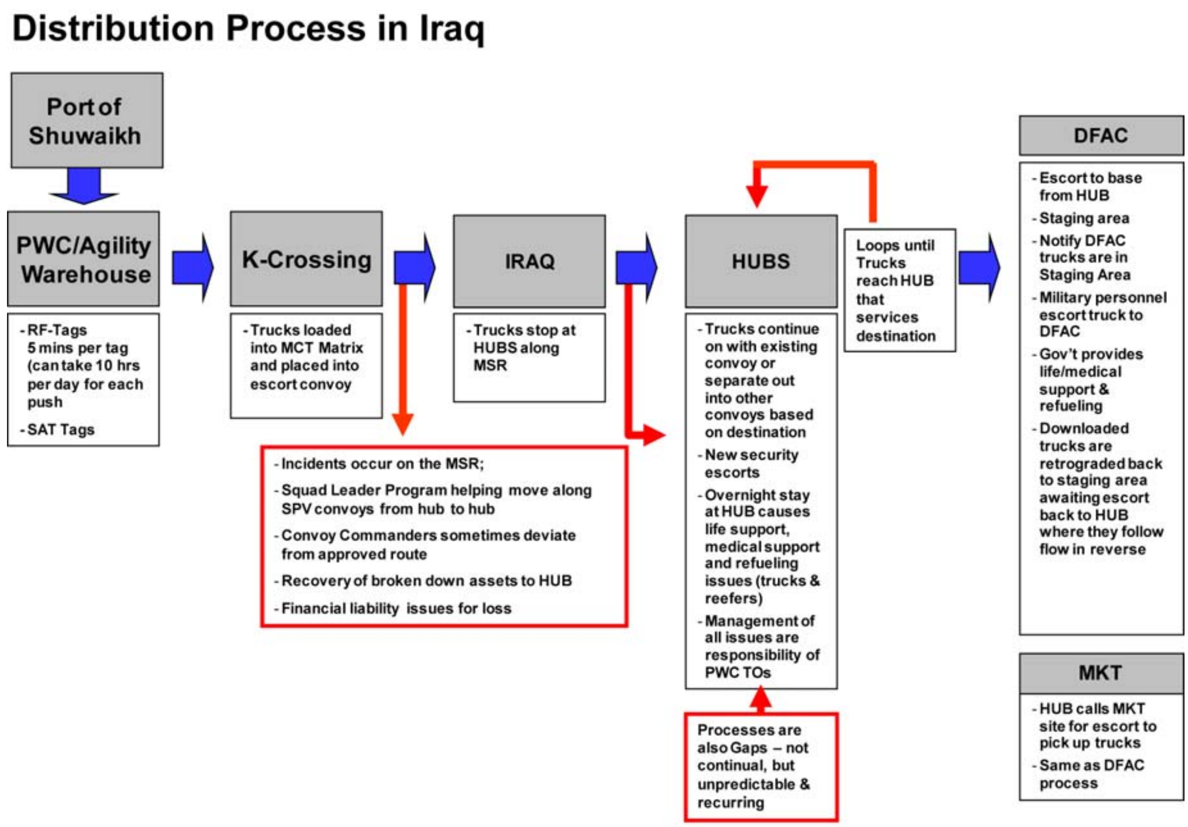
Standard	Expeditionary < 6 Months					Temporary < 24 Months	
						Military	LOGCAP
Ration Cycle	M-M-M	U-M-M	U-M-U w/one UGR (A) meal every third day	U-M-U	U-M-U	U-M-U	21 Day CONOPS Menu
Theater Ration Mix	MRE 100%	UGR (H&S) 34%	UGR (H&S) 56%	UGR (H&S) 34%	UGR (H&S) 10%	UGR (H&S) 05%	Force Provider, LOGCAP or Direct Contract 90 % Supported by SPV Platform 10% Combination of MREs, UGRs Condition based
		MRE 66%	MRE 33%	MRE 33%	MRE 20%	MRE 15%	
			UGR (A) 11%	UGR (A) 33%	UGR (A)+ 70%	UGR (A)+ 80%	
Facilities		MKT, KCLFF, CK, Tents, Refers			MKT, CK, Unit Tents, Force Provider, Refers		Force Provider LOGCAP & SPV
Deployment Days D+	1-20 days	21-30	31-60	61-90	91-180	181 Days to 24 Months	

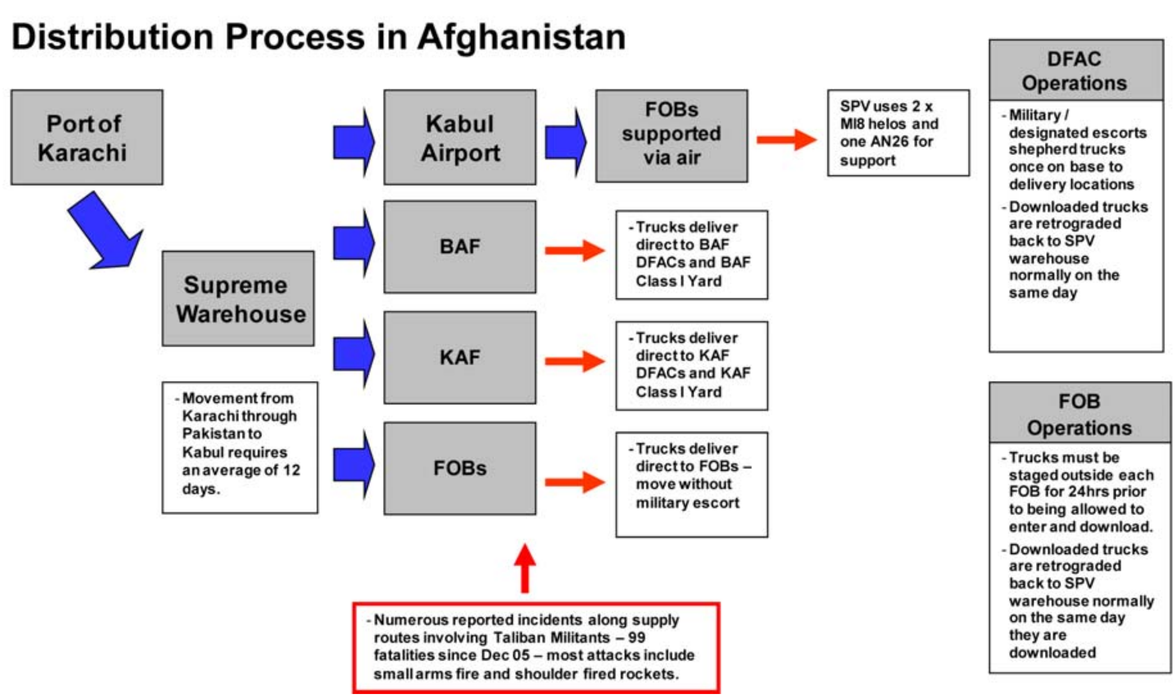
Notes:

1. **Ration Legend: MRE-M, UGR (H&S) or UGR (A) – U, UGR (A) with Short Order Supplemental Menus – UGR (A)+**
2. **Units deploying into developed areas may move directly into the temporary standard depending upon their mission and the theater logistical capabilities at that location.**

Appendix J Class I Distribution – Iraq and Afghanistan

Source: Capt Ed Rackauskas, *Subsistence*, DSCP





Appendix K FOB Fuel Consumption

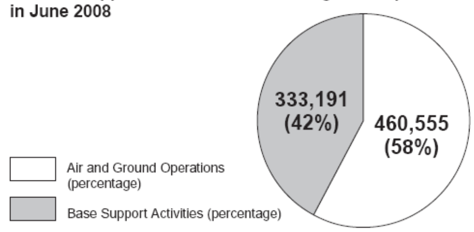
Source: ***Defense Management: DOD Needs to Increase Attention on Fuel Demand Management at Forward-Deployed Locations*****, Government Accountability Office (GAO)**

Figure 8: Camp Lemonier

Mission overview and power structure

Camp Lemonier provides counterterrorism, diplomatic, and development support within the Horn of Africa. It was a former French Foreign Legion base that dates back to World War II. The U.S. Marine Corps took over the camp in 2003, and it was transferred to the U.S. Navy in 2006. Formerly under Central Command, Camp Lemonier is now under Africa Command and is home to Joint Task Force Horn of Africa. It houses about 2,000 U.S. military and civilian personnel, including DOD contractors. The base relies on generators for its electrical power.

Proportion of total fuel consumption (in gallons) reported for base support activities and air and ground operations in June 2008



Summary of fuel consumption for June 2008

In June 2008, Camp Lemonier consumed nearly 800,000 gallons of fuel, and base support activities accounted for nearly 42 percent of the total consumption. According to camp officials, much of the power generated by the prime power system provided cooling for living quarters.[a] The balance of fuel consumption was primarily for air operations, but fuel consumption for June 2008 also included ground vehicles.

Source: GAO analysis of DOD data (pie chart).

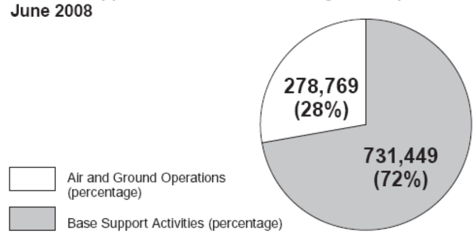
[a]According to a DOD Project Manager-Mobile Electric Power official, prime power refers to mobile, but large, generators that operate off of higher voltages than spot generators and provide large amounts of continuous power.

Figure 9: Q-West Air Base

Mission overview and power structure

Qayyarah West Air Base, also called Q-West, was built in the late 1970s and was an important Iraqi airfield. The primary mission of the base now is to provide logistics for Multi-National Division-North.[a] The base relies on generators for its electrical power. Prime power provides 40 percent of the power, and the remainder is provided by spot generation.[b] Plans call for expanding the use of prime power.

Proportion of total fuel consumption (in gallons) reported for base support activities and air and ground operations in June 2008



Summary of fuel consumption for June 2008

More than 70 percent of Q-West's fuel consumption was used for base support activities. The officials stated that mine-resistant, ambush-protected vehicles generally consumed the most fuel for ground operations during the time period we reviewed, but that the type of equipment consuming the most fuel could vary on a daily basis.

Source: GAO analysis of DOD data (pie chart).

[a]Iraq is divided into major areas of responsibility referred to as major subordinate commands. These include (1) Multinational Division-Baghdad, (2) Multinational Division-North, (3) Multinational Force-West, (4) Multinational Division-Central South, and (5) Multinational Division-Southeast.

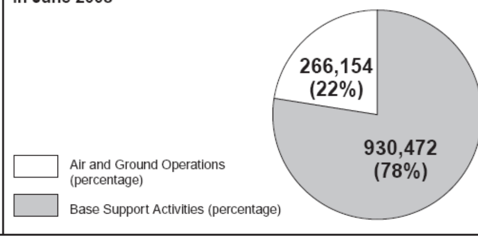
[b]Spot generation, or distributed power, generally refers to generators that operate at lower voltages and produce less power than prime power units.

Figure 10: Camp Arifjan

Mission overview and power structure

Camp Arifjan, through contractors, provides logistics support for operations in Iraq and Afghanistan. The location receives approximately 40 percent of its electrical power from a local utility provide with the remainder supplied by generators.

Proportion of total fuel consumption (in gallons) reported for base support activities and air and ground operations in June 2008



Summary of fuel consumption for June 2008

In addition to electrical power provided through the Kuwait government, Camp Arifjan consumed 930,472 gallons of fuel for base support activities, constituting 78 percent of its total fuel consumption for that month. The fuel was used to provide power to heat and cool facilities and to power machinery and buildings. The greatest users of fuel for ground operations were forklifts, cars, buses and other non-tactical vehicles.

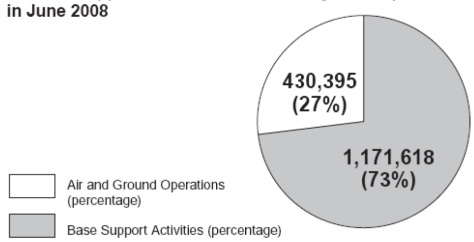
Source: GAO analysis of DOD data (pie chart).

Figure 11: Contingency Operating Base Adder

Mission overview and power structure

COB Adder, located southeast of Baghdad, was established during the initial invasion of Iraq in the spring of 2003. The location relies entirely on spot generation for electrical power. According to a location official, COB Adder's generators are old, past their life cycle, and are in need of upgrade or repair. This has resulted in repeated power outages to the location's tactical operation centers and living areas.

Proportion of total fuel consumption (in gallons) reported for base support activities and air and ground operations in June 2008



Summary of fuel consumption for June 2008

During June 2008, COB Adder consumed more than 1.6 million gallons of fuel, 73 percent of which were for base support activities. The fuel consumed for base support activities was used to provide heating and cooling for structures, field new equipment to units, construct concrete barriers, and support the majority of base operations. The remainder of the fuel consumed at the location was used for ground operations, which include vehicles.

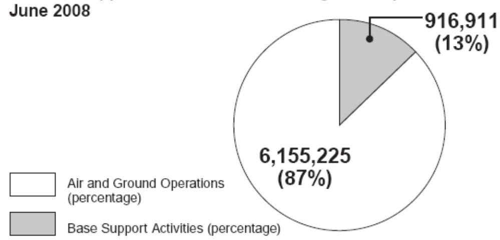
Source: GAO analysis of DOD data (pie chart).

Figure 12: Bagram Air Field

Mission overview and power structure

Bagram Air Field, established in 2001, serves as a logistical hub and air base supporting U.S. forces in Afghanistan. The 455th Air Expeditionary Wing has approximately 3,400 personnel stationed at Bagram. The location relies on generators for its electrical power.

Proportion of total fuel consumption (in gallons) reported for base support activities and air and ground operations in June 2008



Summary of fuel consumption for June 2008

During June 2008, base support activities accounted for approximately 13 percent of Bagram Air Field's overall fuel consumption. Most of the fuel consumed in June 2008 was jet fuel for air operations. The fuel used for ground operations constituted 3 percent of the total fuel consumed and was primarily used for vehicles. Officials told us that the fuel consumed at Bagram Air Field during June 2008 exceeded the amount of fuel received during the same month due to delays and losses during delivery. During that month, officials said that 44 trucks and 220,000 gallons of fuel were lost due to attacks or other events.

Source: GAO analysis of DOD data (pie chart).

Appendix L Tactical Quiet Generators

Source: GlobalSecurity.org

Type	Nomenclature	Model #	Length	Width	Height	Applications
3kW TQG	DED, 60 Hz	MEP-831A	34.8 in.	27.8 in.	26.5 in.	Weapon Systems
	DED, 400Hz	MEP-832A				Missile Systems
						Causeway Systems
						C4I Systems
5kW TQG	60 Hz TQG	802A	50.4 in.	31.8 in.	36.2 in.	Weapon Systems
	400 Hz TQG	812A				Missile Systems
						Causeway Systems
						C4I Systems
10kW TQG	60 Hz TQG	803A	61.7 in.	31.8 in.	36.2 in.	Weapon Systems
	400 Hz TQG	813A				Missile Systems
						Laundry Units
						C4I Systems
						Refrigeration Systems
15kW TQG	60 Hz TQG	804A	69.3 in.	35.3 in.	54.1 in.	Weapon Systems
	400 Hz TQG	814A				Missile Systems
						Well Kit, Printing Plants
						Topographic Support Systems
						C4I Systems
						Hospital Maintenance
30kW TQG	60 Hz TQG	805A	79.3 in.	35.3 in.	54.1 in.	Weapon Systems
	400 Hz TQG	815A				Missile Systems
						Bakery Plant
						ADP Support Systems
						Water Purification
						C4I Systems
						Aviation Shop Sets
60kW TQG	60 Hz TQG	806A	86.3 in.	35.3 in	58.2 in.	Weapon Systems
	400 Hz TQG	816A				Missile Systems
						Earth Satellite Terminals
						Field Hospitals/Schools
						Aviation Ground Support

Appendix M Harvest Falcon Energy & Fuel Demand

Source: Randy L. Boswell, Major, USAF, The Impact of Renewable Energy Sources on Forward Operating Bases

Appendix A – Forward Operating Base Energy Consumption Model

Power Consumer	Qty	Normal Power kW (5)	Demand Factor (6)	Total Peak Demand	Operating Hours / Day	Energy kWh / Day
Harvest Falcon Housekeeping Set (1)						
ROWPU	3	22	1	66	20	1320
RALS	7	7.2	1	50.4	12	604.8
ECU	158	10	1	1580	12	18960
Small Shelter, Admin	16	5	0.9	72	12	864
Small Shelter, Billeting	92	4.5	1	414	12	4968
Small Shelter, Briefing	2	*5*	0.9	9	12	108
Small Shelter, Laundry	2	10	0.9	18	12	216
Small Shelter, Mortuary	1	6.3	0.8	5.04	12	60.48
Small Shelter, Water Plant	2	5	1	10	12	120
Medium Shelter, General Use	3	7	0.7	14.7	12	176.4
Latrine Assembly	4	6	0.8	19.2	24	460.8
Shower/Shave Assembly	4	6	0.9	21.6	24	518.4
9-1 Kitchen	1	*10*	0.9	9	24	216
Refrigerator (ADR 300)	7	*10*	1	70	24	1680
Light Cart, TF-2	4	Internal Generator				
Harvest Falcon Industrial Operations Set (2)						
ECU	42	10	1	420	12	5040
8,000 sq ft Dome, General Use	3	10	0.7	21	12	252
8,000 sq ft Dome, Packing and Crating	1	*20*	0.7	14	12	168
8,000 sq ft Dome, Combat Supply	1	*10*	0.9	9	12	108
8,000 sq ft Dome, Vehicle Ops/Maintenance	2	*20*	0.7	28	24	672
4,000 sq ft Dome	1	8	0.7	5.6	12	67.2
Small Shelter, General Use	5	*6*	*0.7*	21	12	252
Small Shelter, Supply	2	*6*	0.8	9.6	12	115.2
Medium Shelter, General Use	2	*6*	*0.7*	8.4	12	100.8
Medium Shelter, CE Shops	2	*8*	0.6	9.6	12	115.2
Small Shelter, Admin	4	5	0.9	18	12	216
Small Shelter, CE Shops	9	*8*	0.6	43.2	12	518.4
Small Shelter, Chapel	1	7.8	0.9	7.02	12	84.24
Small Shelter, Mortuary	1	6.3	0.8	5.04	12	60.48
Small Shelter, Multipurpose	4	*5*	*0.7*	14	12	168
Small Shelter, Tactical Field Exchange	2	6	0.9	10.8	12	129.6
Containerized Deployment Kitchen	2	*20*	0.9			
Latrine Assembly	1	6	0.8	4.8	24	115.2

Power Consumer	Qty	Normal Power kW (5)	Demand Factor (6)	Total Peak Demand	Operating Hours / Day	Energy kWh / Day
Harvest Falcon Intitial Flightline Set (3)						
EALS	1	20	1	20	12	240
MAAS	3	Internal Diesel Engine				
RALS	1	7.2	1	7.2	12	86.4
Shower/Shave Assembly	1	6	0.9	5.4	24	129.6
ECU	48	10	1	480	12	5760
Small Shelter, Alert Billeting	3	5.4	1	16.2	24	388.8
Small Shelter, Fire Station	3	4.5	0.7	9.45	24	226.8
8,000 sq ft Dome, General Use	1	10	0.7	7	12	84
8,000 sq ft Dome, Propulsion Shop	1	36	0.7	25.2	24	604.8
4,000 sq ft Dome, General Use	4	*8*	*0.7*	22.4	12	268.8
Small Shelter, General Use	12	*5*	*0.7*	42	12	504
Small Shelter, Fuels Lab	1	7.2	0.7	5.04	24	120.96
Small Shelter, Parachute Shop	1	6.6	0.8	5.28	24	126.72
Medium Shelter, General Use	16	*6*	*0.7*	67.2	12	806.4
Medium Shelter, Power/Non-power AGE	2	8.2	0.7	11.48	24	275.52
Aircraft Hangar	2	36	0.9	64.8	24	1555.2
Light Cart, TF-2	8	Internal Generator				
Latrine Assembly	1	6	0.8	4.8	24	115.2
Harvest Falcon Follow-on Flightline Set (4)						
ECU	12	10	1	120	12	1440
Medium Shelter, General Use	1	*6*	*0.7*	4.2	12	50.4
Medium Shelter, Power/Non-power AGE	2	8.2	0.7	11.48	24	275.52
8,000 sq ft Dome, Propulsion Shop	1	36	0.7	25.2	24	604.8
Aircraft Hangar	1	36	0.9	32.4	24	777.6
Light Cart, TF-2	1	Internal Generator				

Total Power: 3,878 Energy: 52,897

Remove from grid and supply with renewable energy- Power: 565 Energy: 7,452

Percentage of Energy Saved: 14%

Amount of power / energy consumed by ECUs - Power: 2,600 Energy: 31,200

Percentage of Energy Consumed by ECUs: 59%

Appendix C – Forward Operating Base Electrical Generator Fuel Consumption Model

Power Producer	Purpose	Rated Power kW	Loading kW	% Rated Power	Operating Hours / Day	Energy kWh / Day	Fuel Consumption gal / hr	Daily Fuel Req (gal)
Harvest Falcon Housekeeping Set								
MEP-806B	On-line ROWPU	50	44	88%	20	880	4.51	90.2
MEP-806B	On-line ?	50	45	90%	20	900	4.51	90.2
MEP-806B	On-line ADR-300	50	40	80%	20	800	4.51	90.2
MEP-806B	On-line ?	50	45	90%	20	900	4.51	90.2
MEP-806B	On-line ?	50	45	90%	20	900	4.51	90.2
MEP-806B	SDC Backup	50	0	0%	0	0	4.51	0
MEP-806B	SDC Backup	50	0	0%	0	0	4.51	0
MEP-012A	On-line Main Power Plant	750	711	95%	16	11376	55	880
MEP-012A	On-line Main Power Plant	750	711	95%	16	11376	55	880
MEP-012A	On-line Main Power Plant	750	711	95%	16	11376	55	880
MEP-012A	Maintenance Gen. Main Power Plant	750	0	0%	0	0	55	0
Harvest Falcon Industrial Operations Set								
MEP-012A	On-line Main Power Plant	750	711	95%	16	11376	55	880
MEP-012A	On-line Main Power Plant	750	711	95%	16	11376	55	880
Harvest Falcon Intitial Flightline Set								
MEP-805B	On-line EALS	30	20	67%	12	240	2.43	29.16
MEP-805B	Backup Gen. EALS	30	0	0%	0	0	2.43	0
MEP-806	SDC Backup	50	0	0%	0	0	4.51	0
MEP-806	SDC Backup	50	0	0%	0	0	4.51	0

Energy Produced Each Day: 61500

Fuel Consumed Each Day: 4880

Appendix B – Forward Operating Base Electrical Generation and Distribution Weight Model

Component	Weight (lbs)	Number of Components	Combined Weight (lbs)
MEP-012A	25,000	6	150,000
MEP-806B	4,063	9	36,567
MEP-805B	3,006	2	6,012
Fuel Bladders	230	3	690
Equipment Rack	450	1	450
Expandable Shelter Container	5,400	1	5,400
Cable Skid	4,603	6	27,618
Primary Distribution Center	6,600	2	13,200
Secondary Distribution Center	2,070	28	57,960
Power Distribution Boxes	38	*20*	760
Secondary Cable Assemblies	*40*	*20*	800

Total Weight of Electrical Generation and Distribution System: 299,457

Italicized numbers are estimates for values not found in Air Force publications.

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